BACTERIOLOGY.

APPLIED TO THE

CANNING AND PRESERVING

...OF...

FOOD PRODUCTS.

BY

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INDEX.

MICRO PHOTOGRAPHS AND FIGURES.

SUBJECTS.

PREFACE.

So far as we know there has never appeared a book written on the subject of Bacteriology, especially as it applies to the canning and preserving industries. That this science should be studied and applied by all persons engaged in such business is a generally conceded truth, and it is with the hope that a great deal of good will be accomplished, and a great many of the mysteries, that have caused so much loss to our packers, may be cleared up. It is indeed marvelous how nearly hand in hand practical work and science travel, for looking through the history of these industries we find methods discovered, devices employed and formulæ adopted and used as the results of innumerable experiments, and where these methods, devices, and formulæ were successful, a true scientific principle was found which ought to have been seen from the beginning, and the great losses in experiments and experimenting saved. How many men who fill the positions of superintendents, managers, processors et al., know anything at all about the scientific part of their work? How many men engaged in these enterprises are groping along in the dark relying on traditions and formulæ handed down as a positive success, and who never awaken to the weakness of their management until something new turns up, until some new menace presents itself? Processors have their rules by which to work, because, for some unknown reason to them, the goods will spoil if treated otherwise. Do you know that years ago Tyndall and Pasteur gave the scientific principle to the world, and against the greatest opposition proved their theories and deductions to be absolutely correct? After all the experiments made in this business we find that these scientists struck the key note and unfolded to us a line of study that gives us understanding. It is with the hope that a higher knowledge of the canning and preserving industries may be obtained here that this little work is launched among the productions of this day.

THE AUTHOR.

CHAPTER I.

INTRODUCTION. CAUSE LEADING TO THE STUDY OF BACTERIOLOGY. SOUR TOMATOES.

In the fall of 1891, a peculiar trouble came to my notice, with a large pack of tomatoes. Many cans when opened appeared to be in good condition, bright, red and sound, but possessing a most nauseating, sour taste. Believing that this was due to a careless use of the soldering solution, chloride of zinc, I had made a careful analysis and could find but a slight trace of this. I was then puzzled to know just what caused the trouble and so I decided to make some experiments. The analysis showed a liberal quantity of butyric and lactic acid, also a trace of acetic acid. Fearing that we had been using a flux which was not pure, an analysis proved the theory to be incorrect and it then dawned upon me that the same old trouble that I had many times seen in packing corn, had in some unaccountable way taken possession of the tomato canning. Corresponding with others engaged in packing tomatoes, I found that several had experienced trouble of this nature to some extent but not to such an extent as to cause alarm in the canning of tomatoes. I knew that many canners had experienced heavy losses in canning corn and some fruits, where the seeds were left in the can. No one seemed to know what to do under the circumstances; liberal rewards were offered to anyone who could save the corn, etc., by some of the canners who were losing so much goods, and I knew of several who were severely imposed upon by unscrupulous persons, who claimed to know how to prevent the complications.

Up to this time I had never given a thought to the scientific principles involved in canning and preserving. Talking over the rules with experienced processors, I found that they were carrying on their work in a blind way and following rules which the expensive teacher, Experience, had given them without inquiring into the principles of science. So long as no new complications presented themselves they got along all right, but when the conditions changed, and the products were coming in too fast, and the changes

in the weather were unusual, the canners suffered losses because they were following iron-clad rules and durst not launch into new channels lest their losses would prove overwhelming. They followed the "rule of thumb" and if losses came they were put down as inevitable and they called them a part of the expense of canning.

Realizing that it was time to begin a scientific study of the processes of canning and preserving and that it was necessary to know how to meet all these difficulties which were constantly arising, and so follow the example set by the brewers after Pasteur had revealed the nature of their troubles with sour beer, I decided to take up the study of bacteriology and apply the knowledge to this business. Since that time I have constantly studied this science and the further I go the more light it throws upon the subject, and I am now prepared to say that every man who is engaged in these enterprises should immediately begin to give some of his attention to the subject. By arranging a little room and procuring a few instruments, the subject could be studied during the dull seasons and the knowledge applied during the canning season when the actual process of canning begins.

Another incentive for taking up the study of bacteriology and applying the knowledge to this industry, was my hope that goods of a very superior quality might be obtained, simply because with a certain knowledge of just how to treat each kind of goods to insure its perfect sterility, and therefore its keeping qualities, without doing anything in excess of its requirements, to wit, if under certain conditions a temperature of 250° F. for seventeen minutes, would keep tomatoes, and if you were scientifically correct, you would avoid processing the same goods thirty minutes. By this you would get a better flavor and of course your scientific knowledge should receive the credit. As I stated before, I decided to take a course of study in this science, which I did. I took up a number of experiments with sour tomatoes, which I will now explain because they have a bearing on a part of the work which is to follow. I opened a number of the sour cans of tomatoes, and after filtering some of the juice through a cheese cloth, examined it under the power of a microscope of 1000 diameters. I found quite a number of small round globules, which at that time I was unable to understand. They seemed to be motionless except a slight quivering which is termed Brownian motion. There were small rods and little fine dots sometimes alone, sometimes in pairs, and looked like ants. There were also small forms barely perceptible and one or two specimens of a very large germ. The view given in the accompany-

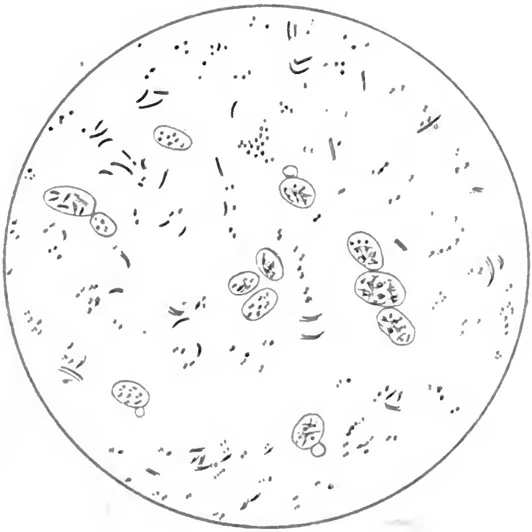


Figure 1
MAGNIFIED X 1000.

ing plate is just as it was taken. I left this juice under a cover-glass in a warm room for two days and it remained practically unchanged, and I believed that the germs were dead and so they were. To determine that this souring of tomatoes was caused prior to the processing was my only solution, because the germs were lifeless. I took a number of cans and heated them, and I could determine which were sour because they would be slow to draw in again, due to the presence of a small quantity of carbonic acid gas which had been absorbed by the tomato and which the heating had liberated. The gas, as I afterward found out, was that which had been capped in the can while the tomatoes were fermenting before processing. Taking a number of swelled cans of tomatoes in various degrees of fermentation, I cut them open and filled new cans with the contents and immediately gave them thirty minutes boiling, at 212° F. I had four cans, A, B, C and D. A was taken from a can very badly swelled and hot with fermentation. D was taken from a can which had just started to ferment, and B and C were taken from cans which were bulged out just a little more than D. After processing these cans in water for thirty minutes, I took them out, chilled them and set them to one side to await results. D drew in first and it was several days before A finally looked all right, but it was quite short in weight and not nearly full. I decided to open these cans and determine if I had anything similar to my sour tomatoes, and you may imagine my surprise to find them almost exactly the same; especially was this true of B, C and D, while A represented an unusual example, being too violent. It was evident then that our sour tomatoes were sour before the processing and that the heat had killed the organisms, but the unpleasant results of the fermentation were absorbed by the tomatoes in the can together with whatever carbonic acid gas was present in the fermenting tomatoes. The question then arose, where and when was this fermentation started and what were the causes. We found that about twenty per cent. of the entire pack had suffered during the month of September when the weather had been quite warm, and warm rains had been frequent. The farmers had brought in the product very fast and we were bothered with a gray mold whenever the tomatoes stood in the boxes for a few hours.

The peculiar manner of our canning had been to heat the filled cans in steam boxes and then take them to the capping machines. It frequently happened that these would accumulate ahead of the automatic capping machines, particularly when something would get out of order about them, when they would sometimes stand for a

half hour in a temperature of 90° to 100° F. Here then was where the fermentation started and this was the secret of the whole trouble. A scientific knowledge would have obviated this difficulty at once and saved a severe loss. During the next season I verified this theory by making actual experiments in this line, by taking a number of cans and allowing them to stand in a warm place for a considerable time and also taking some which did not stand. The former were without exception sour and unfit for food after the process, while the latter were perfectly good in every respect.

CHAPTER II.

BACTERIA DEFINED. FORMS. MULTIPLICITY. FUNCTIONS. DIVIDED INTO TWO CLASSES. DISCOVERIES. SPONTANEOUS GENERATION. BACTERIA IN THE ATMOSPHERE LISTER'S ANTISEPTIC SYSTEM. MICROSCOPICAL OBSERVATIONS. CHEMISTRY OF FERMENTATION PTOMAINES. WHAT CLASS OF BACTERIA PRODUCES THESE POISONS. RESULT OF PTOMAINE POISONING.

We will now take up the study of bacteria, particularly the varieties peculiar to the destruction of the various products which are canned in hermetically sealed packages. We will study their life, history, their mode of propagation and the conditions most favorable for their development. We will also go into the subject to determine safe methods to guard against their action.

Bacteria are the lowest form of living things. They are organisms of various forms and shapes, round, rods, ellipsoid, thread, spiral, dumb-bell, spindle, etc. Each is a small speck of protoplasm called a cell and exceedingly small. Micrococci measure about $\frac{1}{25000}$ part of an inch in diameter. They multiply with marvelous rapidity and if suitable conditions were all right one germ of many varieties could produce or multiply to the extent of 5000 billions in three days. Such conditions however do not ordinarily exist and many of them die off because of peculiar changes produced by their own action on the medium, upon which they are thriving. The usefulness of many of these bacteria in destroying accumulated vegetable and animal matter is very great. If it were not for these minute organisms all this matter would accumulate and would not be reduced to elementary forms so necessary for new plant and animal life. All things that die would remain and the animal and vegetable kingdoms would soon become extinct. A dead animal or dead

vegetation under the action of these germs is with wonderful rapidity reduced to the elementary forms to nourish new vegetable and animal life.

We may divide for our consideration bacterial life into two distinct classes, viz: those which merely act as ferments and are not disease producing in man, and those which produce disease. With the former we have largely to deal because it is by their action that the complications arise in the preservation of food products. But we have also something to say of the latter because of the results of their action at times on food products, causing ptomaines which are alkaloids, and deadly poison to man, and which have been the cause of so much discussion among medical men in the late years, from the fact that people have at times died from eating certain kinds of fish and meat. Cheese and ice cream have been known to cause the death of persons under most seemingly unaccountable circumstances.

As a rule bacteria are colorless and refractile in a clear liquid but may be colored and identified by their affinity for certain kinds of dyes which give them a clear outline and makes them easy to study under a suitable instrument. The first man to discover that there was such a thing as bacteria was Anthony van Leeuwenhoek, a native of Delft, Holland, who in 1675, with only a crude instrument of his own design, discovered minute organisms with motility in decayed matter. He says: "I saw with very great astonishment that there were many small animals which moved about in a most amusing manner, the largest of these showed the liveliest and most active motion, moving through rain water or saliva like a fish of prey darts through the water; this form, though few in numbers, was met with everywhere. A second form moved round often in a circle; these were present in greater numbers. They were tiny, in addition they moved forward so rapidly that they tore through one another like a swarm of midges and flies buzzing in and out between one another. I had the impression that I saw several thousand in a single drop of water or saliva which was mixed with the matter under observation not larger than a grain of sand. Some were curved, some straight, lying irregularly and interlaced." These remarkable statements made at so early a date, give us the first history of the rod shaped bacteria bacilla, spirilla and round shaped micrococci. These statements caused a great deal of excitement and research by scientists, and many peculiar theories were advanced. Otto Friederich Muller, of Copenhagen, was the first man who undertook to classify the different kinds of bacteria, and he certainly

made remarkable progress, considering the very crude microscopes made in his time. Other scientists took up the work and the opposition took the ground that these scientists were not dealing with germs, but merely albuminoid matter found in the air. The matter was not cleared up until the time of Tyndall and Pasteur, who brought the science out of its chaotic state and proved their work step by step, and it is due to the two men who overthrew the theory of spontaneous generation that this science is to-day on such a sure footing.

For many years the theory that these organisms were a spontaneous production of decaying matter, was generally accepted as truth. When meat was exposed in hot weather, it soon filled with worms, and it was thought that they generated of themselves, until someone covered it with wire gauze and the flies deposited their eggs on the wire and proved the fallacy of the theory. The belief in spontaneous generation was entertained by many scientists prior to and contemporaneous with Pasteur, among whom most notably were Schultz and Von Liebig. They took infusions of mutton broth and different vegetables, and having sterilized them perfectly by heat so that no micro-organisms were visible under the microscope, they allow them to stand open and exposed to the atmosphere for several days, examining them constantly. Suddenly putrefactive organisms and ferments peculiar to the infusion, would make their appearance most unaccountably to them, so they advanced the theory that life was spontaneous, and even built up a framework for the existence of all living things on this theory. Tyndall and Pasteur were not believers in this theory, and took up a series of experiments to demonstrate that the germs were deposited from the air or atmosphere. They had very great difficulties to contend with, because it was generally thought that these low forms of life were easily destroyed by boiling at a temperature of 212° F. It was found however, that many of their infusions would break down, become turbid, evolve carbonic acid gas, after having been subjected to the boiling temperature for several hours. The opposition strengthened themselves in their theory because they, too, had tried these experiments, and the result was that in nearly all cases they were unsuccessful in preserving their infusions, especially those made from meats and some vegetables, which had bacteria of more resistant power than others. After making various experiments in test tubes where the glass was drawn to a fine point at the top to allow the steam to escape during the heating, and while still boiling they closed the escape by melting the glass together, they were enabled to

obtain many perfectly sterile infusions, which kept for a number of years perfectly clear and transparent. They adopted various temperatures, both continuous and discontinuous, and were able to sterilize any kind of fluid. Their failures in many cases were due to their test tubes not being full of liquid so that the air space between the boiling liquid and the point of exit would contain the dry spores of bacteria which would afterward develop when the liquid cooled off.

Having accomplished the overthrow of the theory of spontaneous generation, Tyndall even went further and demonstrated by the question of a doubt that the atmosphere furnished these low forms of life. He made a pure air chamber and covered all over on the inside with glycerine; this chamber had windows through which he passed an electric beam. So long as there was any floating matter within the chamber, the light would be refracted just as a ray of light passing through a dark room is refracted by the particles of dust, which we have all seen. When the light ceased to be refracted and the beam passed entirely through the chamber without lighting it, it was evident that the particles had settled and stuck fast to the glycerine. In this chamber then he placed many different kinds of sterilized infusions and they kept without showing any signs of breaking down or fermenting. It is to these two geniuses, Pasteur and Tyndall, that we owe all that we know of the method of sterilizing, and their deductions come to us who are in the canning and preserving industries, as a solution of all our troubles. Bacteria, then as we learn, are present everywhere in the free atmosphere, and we find them present in quantities or numbers in proportion to the amount of organic matter which is undergoing decomposition. They are present in the air, clinging to dust or any floating matter and if no suitable medium is found by them to enable them to vegetate they become hard and dry, and in the course of time will die. Pasteur, however, demonstrated that many varieties would live for two years. When we consider the vast amount of organic matter which is undergoing decomposition every year, the grass, the leaves, all vegetation and animal life, it is no wonder then that the atmosphere is everywhere laden with countless numbers. Many of the different varieties are useful directly to man; the butyric ferment for instance is so useful in ripening cheese and making butter, that this form is cultivated and employed in some of the best creameries, just as the brewers cultivate and sow their yeast. Just how or when these low forms of life first made their appearance, we do not know, but it is likely that they have existed

since creation, and their origin like that of every living thing, is shrouded in mystery. It is a surprise that the existence of this world of living things should have remained unknown to man through so many centuries. When we think of the incalculable value of such knowledge, we wonder how man could get along without knowing of their existence. The dreaded diseases came on man and he called them the plague, sent by God upon man. We are thinking of the terrible plague, the Black Death, which made its appearance and nearly depopulated the world at one time. The superstitious people crowded together, offered prayers and made offerings, used charms and did everything imaginable to stop the progress of the disease. They did not know that it was caused by these low forms of life, for if they had known it, they could have taken sanitary measures to stop it. In the late Civil War, limbs were amputated without the use of the carbolic acid spray, and men died of gangrene and blood poisoning. Lister was the discoverer of the antiseptic spray to keep the germs in the air from acting on the tissues, when surgical operations were performed, and we can now see where many brave and valiant soldiers perished from blood poisoning where this carbolic spray would have saved their lives.

Owing to the minuteness of these organisms the study of their life and nature becomes a science, and is a field for advanced research. It is not like taking up the study of things we can see with the naked eye, and watch from day to day their habits and purposes and results, but it is a study when only a small field of observation can be watched for a limited time and the results can only be studied as we watch their action through a powerful microscope. With the best instruments obtainable in this advanced age, we find ourselves limited for the want of sufficient light, for the greater the magnifying power of the glass, the greater amount of light is required, and it must be a peculiar light too, not glaring as the direct rays of the sun, but the soft rays of light reflected as from white clouds or the electric light. Owing to the transparency of most of these organisms it is necessary, especially for the examination of the smaller forms, to use certain kinds of dyes, otherwise you might examine a field and very few forms would be visible. It is very interesting to watch the working of bacteria on the particular substratum that you wish to examine. For instance, if you desire to examine fermenting corn you would take some of the juice and put a small quantity under a cover glass, which is a very thin piece of glass about $\frac{1}{200}$ of an inch in thickness, and when you brought the field to a proper focus you would find a very turbid view and

you would be unable to gain much of an idea of the germs you wished to examine. You could filter a small quantity of sweet juice and then by dipping a needle in the fermenting juice, transfer some of the germs to this and then transfer a small quantity to the plate, and place the cover glass over this to diminish evaporation, then you could watch the active bacteria begin their work of decomposition. In coloring the bacteria, a small quantity of methyl blue or eosine will often bring them clearly to view. It is in the results of bacterial action that we are most interested, as they bring about chemical action and change the atoms from one group of molecules to another and form new compounds and create gases. If, for instance, we take sugar and allow the yeast plant to work on a prepared solution, we find that it is broken up into different forms. We will represent one molecule of sugar by its atomical symbols which is $C_6H_{12}O_6$ which is six atoms each of carbon and oxygen and twelve atoms of hydrogen. By the action of the yeast plant, which is called saccharomyces we get $2CO_2$ (carbonic acid) $+ 2C_2H_6O$ (alcohol) which are two distinct substances and not resembling at all. Now if the putrefactive ferment butyricus amylobacter acts on the alcohol we will have $2C_2H_6O$ (alcohol)$=C_4H_8O_2$ (butyric acid)$+ 2H_2$ (hydrogen) or if we let the lactic ferment act directly on the sugar in conjunction with the butyric ferment, we will have the sugar converted directly into lactic acid which in its turn is converted into butyric acid, carbonic acid and hydrogen. $C_6H_{12}O_6$ (sugar)$= 2C_3H_6O_3$ (lactic acid) $= C_4H_8O_2$ (butyric acid $+ 2H_2$ (hydrogen).

Thus we see our molecule of sugar broken up first into two molecules of lactic acid which in its turn is broken up into two fatty acids, and two molecules of hydrogen, or in other words one molecule of sugar broken up into five molecules, which is the tearing down process of these organisms to reduce or decompose substances into elementary forms. I do not mean to say that the process ends where I have brought it, for there are still lower forms of bacteria which take up the work and reduce these molecules still further until they take simple forms, even elementary forms. I think the above chemical formulae should be very interesting and instructive, as they give you the idea of bacterial action better than any description in words.

We have been describing the action of certain bacteria which act only on dead matter which are not classed properly with the disease germs. To be sure if we take into our stomachs fermenting substances we are liable to suffer with some disorder, and perhaps

severe sickness, but the difference between this action and the action caused by disease germs properly speaking is very great. We will enter into a description of the various diseases produced by this class of bacteria further than to observe their action on certain foods which when taken into the stomach produce certain kinds of poisoning, resembling arsenic and strychnine. Brieger obtained from pure cultures of the typhoid bacillus acting on some suitable medium, a ptomaine which termed typhotoxin, and from the tetanus bacillus he obtained tetanotoxin. The vegetable kingdom furnishes many substances that have an alkaline reaction, combine with the acids and form salts, which if injected into animals or taken into the stomach cause poisoning, viz: nicotine, morphine, brucine, strychnine and hydrocyanic acid. So these bacteria of disease or pathogenic organisms, which are of vegetable nature, can produce poisons in food products where they may happen to find a substratum favorable to their growth. In plainer language then, since the higher order of plant life can furnish these dreadful poisons, so the lower vegetable forms produce poisons just as deadly and of nearly the same reaction as the higher forms. Nearly all the known pathogenic organism produce poisons which would properly be termed ptomaines. Putrescine ($C_4H_{12}N_2$), cadaverine ($C_5H_{16}N_2$) are ptomaines, the latter is produced by an action of the cholera bacilus on egg albumen. Neurine ($C_5H_{12}(NO)$), and choline $C_5H_{15}NO_2$, are also produced in putrefying flesh by the agency of pathogenic bacteria. We find also another poison growing naturally in a kind of poisonous mushroom and also produced in putreying fish by bacteria. This ptomaine is muscarine ($C_5H_{15}NO_2$), and acts on the muscles when eaten. Oysters and mussels are very liable to the action of certain bacteria which produce mytilotoxine, $C_6H_{15}NO_2$). Tyrotoxine ($C_7H_{17}NO_2$) is found in cheese and ice cream, where these foods have undergone a fermenting process by the agency of disease germs. The diphtheria germ, Klebs-Loeffler bacillus produces a toxic poison, so also do the bacilli of cholera, typhoid, tetanus others.

Studying over these deductions and chemical changes, we see that combinations are easily upset, atoms from one set of molecules fall down and are taken up by other molecules, forming new substances by these mere changes in arrangement. If we cannot see the exact changes chemically made, we can see the agents at work and we can see how they perform the work.

The word ptomaine comes from the Greek word πτῶμα, which means "cadaver" and was bestowed upon them by Selmi, an Italian

chemist. Delafontaine gives a very interesting explanation of these poisons: "During the incipient state of putrefaction there are frequently produced various compounds, some of which possess intensely poisonous properties. They are called ptomaines. They seem to have led some experts into trouble, for the reason that some of them produce symptoms similar to those of various natural poisons such as strychnine, morphine, nicotine, etc. Such poisons have been extracted from cheese, milk, especially in the form of ice creams, and various preparations of meats, such as sausage, smoked meat and fish.

"The action of some of these upon the healthy man very much resembles that of arsenic and other like irritating poisons. Almost every summer, one chemist or another has to investigate cases of poisoning from ice cream, especially resulting from parties or picnics, where a number of people are made more or less sick from the effects of eating the compound. The first impulse of victims and friends is to ascribe the trouble to the presence of copper, lead or zinc absorbed by the cream from the freezers. Sometimes the blame is laid at the door of the flavoring extract employed, especially if it chances to be vanilla. But almost invariably the closest chemical analysis fails to sustain the suspicions and leads to the extraction of a ptomaine identical with or closely allied to that sometimes found in cheese. Incidentally it may be stated that on the whole, the poison-tainted articles exhibit no bad taste or smell, that would act as a warning to the consumer.

"As regards some of the symptoms frequently exhibited, they are like those of a very irritating poison. Among other cases, I once was called to examine some meat eaten by fifteen persons who were poisoned. They developed acute inflammation of the stomach and bowels, repeated vomiting and purging, with great loss of strength, clammy perspiration and cold extremities. There was nothing in the appearance, taste or smell of the meat to indicate that it was unsound, and yet I could extract from some parts of it a poison which was undoubtedly a ptomaine.

"Poisoning by ptomaines is by no means uncommon, yet many suspected cases are due only to over indulgence in strongly spiced articles and too much drinking of beer," etc.

There is an interesting article also in the Scientific American, which gives some useful information on the subject of ptomaines. It says: "Within the last few days a number of persons in New York City have died from ptomaine poisoning, so that public attention is now directed toward the mysterious nature of these

poisons, which are not generally well understood. 'Ptomaine' is a generic name for alkaloid bodies formed from animal and vegetable tissues during putrefaction and the similar bodies produced by pathogenic bacteria. Very often, perhaps generally, the degeneration in the food product is not far enough advanced to offend either the taste or sense of smell; consequently, suspicion is not excited, and a person eats or drinks something which contains enough of the poison to make a great deal of trouble, if the result is not fatal. We often hear, in the summer, for instance, that persons who attend a picnic were stricken with a violent illness, and that the physicians in the neighborhood were kept busy for hours. The fact is developed that only those who ate ice cream were made sick. Sometimes it is reported that some one has poisoned the food maliciously, but it is known that the cause of most, if not all, of these distressing experiences was the presence of ptomaines in the milk out of which the ice cream was made.

"It is not an easy task to trace the history of milk back far enough to reveal the precise conditions under which the ptomaines were developed, but it is believed that failure to properly cool the milk immediately after it was taken from the cows, is a partial explanation of the evil. Warm weather favors this condition. The ptomaines of ice cream tyrotoxicon are particularly to be dreaded, as well as other poisons, such as mytilotoxin, found in mussels.

"It is not pleasant to contemplate that the air we breathe and the water we drink, and a large proportion of our food abounds in bacteria of different kinds. Most of them are, fortunately, harmless, or should be, if proper precautions are taken. Milk is far from being the only medium for the transference of this poison to human beings. A great variety of solid foods of animal origin are also likely to develop ptomaines. One frequently hears of poisoning by *canned goods*, such as potted meats or canned salmon, for instance. In some cases a metallic agent, perhaps the solder, is the cause of the trouble, but in the majority of cases the sickness, especially if it is intestinal and painful character, is due to ptomaines. To all appearances, the food may be entirely fit for consumption, and perhaps none of those employed in the canning house may be responsible, but the chances are that *unperceived* putrefaction has set in and that ptomaines have been produced.

"Fresh fish and oysters are not exempt from the tendency to develop ptomaines. Indeed, fish was one of the first sources from which these poisons were obtained by chemists. The symptoms of these poisons are vomiting, nausea, diarrhoea and retarded respira-

tion, and in advanced stages, coma.

"There is no known antidote for this poison, though of course emetics and purgatives should be used where the poison is suspected. There are numerous ptomaines in the body, but they are absorbed by the oxygen or expelled by the bowels, liver and lungs. If not, they strike the nerve centers and sickness results. The real cause of many mysterious deaths is ptomaine poisoning, but there are, of course, many mysterious deaths due to other causes. Many cases of ptomaine poisoning do not result seriously at all."

CHAPTER III.

BACTERIA. MANNER OF PROPOGATING. DESCRIPTION OF VARIOUS FORMS. CHARACTERISTICS. MOLD FUNGI.

The multiplication of bacterial forms vary in different organisms, and it may be well to take up the study of these different forms before engaging our attention on the various organisms peculiar to the decomposition of food products.

Multiplication by division is a common mode, especially with the spirillum and bacillum. Transverse lines become visible, which increase and become gelatinous. The organism separates at these places and the process begins over again. Under the higher powers of the microscope bright shining spots appear within the protoplasm of the germ cells, which are the new spores or life forms which will, under suitable conditions, increase and break away from the parent cell and develop into full grown cells themselves, and these spots will again appear within their walls, and so the multiplication goes on until the conditions become unfavorable for their nourishment. These favorable conditions depend of course on the amount of material exposed to their action, and the temperature sufficiently warm for their vegetating power, which for the great numbers of bacteria must be from 60° to 90° F., but there are some exceptions among the alcoholic ferments where the temperature can fall to 36° or 38° F. The conditions favorable to the propagation also depend on the compounds formed by their own action on the particular substrata which they are causing to ferment. Sometimes an acid is generated which will kill them, and that acid may be due to their own action. The condition will become favorable, too, when the organisms have performed their work. Other forms may appear and take up the work of disintegration where the first form left off, and so after these forms have fulfilled their work, still others may appear on the new

medium so formed and find it favorable to their peculiar action. During the process of germination any particular form of bacillus may change in character from its peculiar form as known under ordinary conditions. A rod shaped bacterium may assume the shape of a curved form like the spirillum or thread-like as the leptothrix and round like the coccus. These various forms of the same bacterium have caused considerable trouble in classification, because they may have the appearance of a different variety or specie. The figure No. 2 will give some idea of the different forms of bacteria.

Figure 2.

a—GERMINATION OF SPORES.
b—BACTERIA WITH FLGELLA.
c—SPORE FORMING CELLS.
d—ZOOGLOEA.
e—COCCI.
f—DIPLOCOCCI.
g—STREPTOCOCCI OR CHAINS.
i—SPIRILLA AND VIBRIOS.
h—LEPTROTHRIX.

When germination takes place by spores the appearance of the mother germ darkens and appears granular when a certain point becomes prominent and it swells rapidly, using up the protoplasm of the cell in forming the new growth. Sometimes the former cell will not expand again, but appears to dry up, in which case the life is maintained in the spore which still clings to the mother cell. In a suitable fermentable substance, the spore will germinate, first swelling to unusual size, when the spore within will burst through

See Figure 4.

the wall and there will appear two germs where formerly only one was visible.

There are anthrospore and endospore forms of bacteria. The endospore bacteria form their spores on the inside of the plasma or wall of the cell, while the anthrospore bacteria do not. The zoögloea forms of bacteria are peculiar to slimy formations, so that when you observe any fluid of a ropy nature, as sometimes happens with peas, it is this form of bacteria largely the cause of such action, but there are of course other reasons for ropiness in canned peas. These bacteria grow very fast in colonies almost pure naturally.

The spore formation of the yeast plant, saccharomyces, is most interesting. The view of these cells budding as seen under a power of 1000 diameters in the microscope, is most interesting because they can be seen so plainly, and their appearance is beautiful. In fact the microscope opens up a new world in the vegetable kingdom and the study is most fascinating.

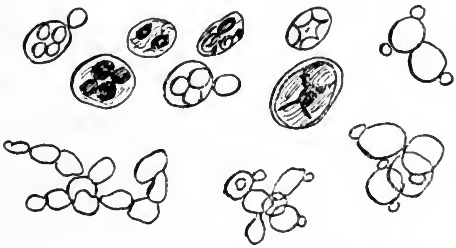


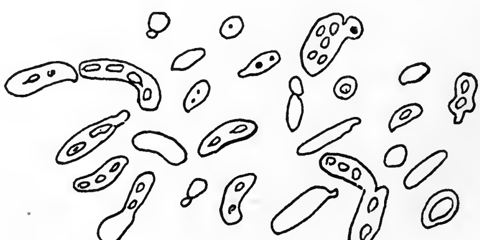
Figure 3.

I took a quantity of filtered tomato juice and placed a culture of these alcohol ferments in it, and the next day I transferred a single drop under the cover glass, filling the slight excavation and laying the cover glass over this to prevent to a certain extent the evaporation of the liquid. I located a few cells and watched them closely; I detected shining spots within the cell walls which appeared to be swelling. After a time I was awarded by seeing a slight protuberance on one side of a cell which increased rapidly in size, remaining attached to the parent cell. After a time other cells began budding, and then I noticed that the first bud had fully developed and was in its turn showing signs of germination. In a short time it sent out a bud and the mother sent out another one in the opposite direction. In a few hours I again examined the view and the beautiful scene was laid out before me as the following illustration will show. All this occurred in a field not larger than a pin point, and no doubt

would have been much more abundant in development if the oxygen had not been partially cut off by the cover glass. I then glued the cover glass fast to the glass slide, and in a very short time the glass burst from the pressure of the carbonic acid gas which was being liberated freely. There appeared also other forms of bacterial life from the atmosphere in zoögloeas and the lactic bacteria were also visible, appearing in little short rods.

The spores of the saccharomyces, as I stated, began to show themselves within the wall of the cell, and exerted such a pressure in swelling as to push through the wall, and after sending out several buds would turn dark and appear to shrivel up. I met also with cells which sent out buds which, when developed, would break away from them entirely. I examined all these specimens in a temperature of 70° to 80° F., which probably accounts for the appearance of other forms in the illustration. The true alcohol ferments may be cultivated almost pure at a temperature of 36° to 40° F., and while their development is slow, they are able, however, to accomplish fermentation, without the interference of other organisms which will not vegetate except in higher temperatures. This peculiarity of the yeasts make the brewing of beer comparatively easier than the old method where little attention was paid to temperatures.

A peculiar film appeared on the tomato juice that I spoke of before, and gradually became thicker and wrinkled in appearance, and the saccharomyces seemed to stop their action and settle down to the bottom of the glass. I examined the flim under the microscope and recognized it as the mycoderma cerevisiae and mycoderma vini, and I found that this film was using up all the free oxygen from the air and so depriving other germs of that very essential element. The cells are various shaped, some round, some long and almost transparent. The spores are easily seen and have a restless movement within the walls of the cell. This form is quite common and appears on the surface of many of the fruit juices.



MYCODERMA VINI AND CEREVISIAE.

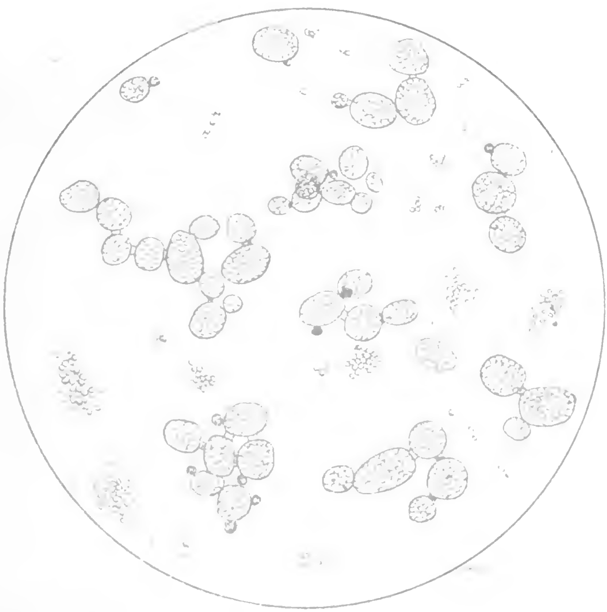


Figure 4

MAGNIFIED X 1000.

The growths of the mold fungi are also interesting, because we can see them with the naked eye to attain the height of an inch sometimes. They have a characteristic plant form and thrive on all liquids of a slightly acid nature, especially fruit juices. The first mold I will describe with reference to its growth, is the pencillium glaucum, which starts from a spore sending out long branches which have the appearance of lengthening out and dividing, like the branches of a bush with joints. When these grow to a certain height the tuft branches produce a large number of conidia, so that the whole surface of a patch of the pencillium glaucum will be covered with millions of these little round cells, each of which is able to start a new plant whenever it falls upon a suitable medium. As a body they present a grayish blue color, and look smaller than the yeast germs.

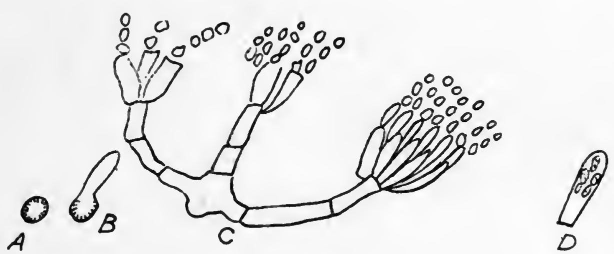


Figure 6.

PENCILLIUM GLANCUS.

a--CONIDIA.
b—CONIDIA SENDING OUT A BRANCH.
c—REPRESENTS THE BRANCHES WITH CONIDIOPHORES AND THESE BEARING NEW CONIDIA OR ROUND CELLS WHICH ARE SEED.
d—CONIDIOPHORE WITH THE SPORES OF THE CONIDIA, BEFORE THE CELL WALL IS RUPTURED.

ASPERGILLUS GLAUCUS.

Aspergillus glaucus is a mold fungus, somewhat similar to the pencillium in the manner of its development and production of conidia. Its peculiarity is the spiral forms of its ascogonium, which is enveloped by the hyphae. This is a very common variety of mold which grows in abundance in damp places.

MUCOR RACEMOSUS.

This is a mold fungus which grows at ordinary temperatures on acid surfaces of fruit juices, or in any damp place where a fermentable substratum is a base of growth. This fungus grows luxu-

riantly on bread and attains a considerable height. The branches and sporangia have about the same characteristics in their formation of spores that the two former ones have, that we have studied. In addition, this fungus has the power to propagate by budding, resembling in many respects the true yeast fungi. The spores are colorless. When mucor racemosus is submerged in a fermentable liquid the sections appear to swell and become large and oval shaped, filled with a highly refractive plasma. They separate at the lines of demarkation and begin budding. The conidia or spores have the same characteristic and resemble the saccharomyces very much. They sometimes germinate in this way when cultivated on a solid substratum.

MONILIA CANDIDA.

This fungus is a white or grayish colored mold which grows from the spore just the same as the other varieties we have examined, and pear shaped or elliptical spores form on the ends of the branches. It is found on sweet, juicy fruits, and when submerged will produce alcoholic fermentation and will form a white film on the top of fruit juices.

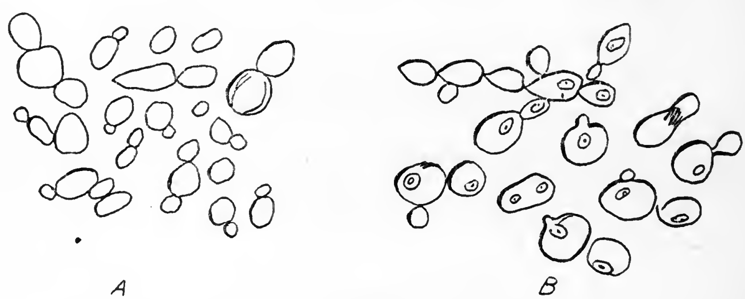


Figure 7.

MAGNIFIED X 1000.

a— MONILIA GROWING WHEN SUBMERGED.
b—MONILIA CELLS OF A FILM FORMATION.

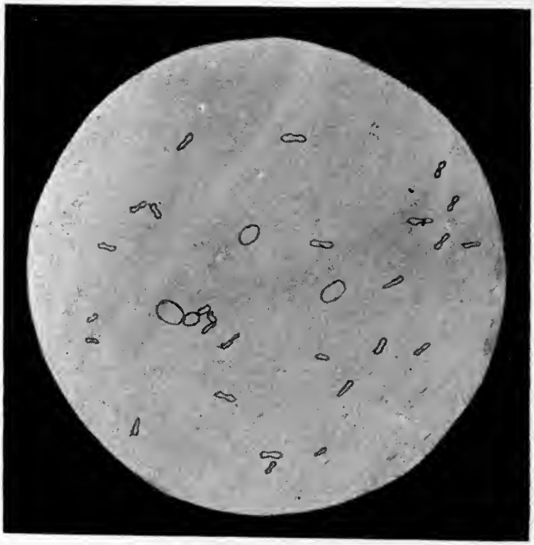


Figure 8.

MAGNIFIED X 1000.

BACILLUS LACTICI ACIDI-SOUP SUBSTRATUM.

CHAPTER IV.

BACTERIA COMMONLY FOUND IN DECOMPOSING FRUIT AND VEGETABLES. MICROSCOPICAL VIEWS AND DESCRIPTIONS CHARACTERISTICS.—STERILIZATION.

It is not my purpose at this time to take up a complete list of the various bacteria found in the many kinds of fruit products, but only a few of the more common varieties, in order that the reader may become familiar with these forms and understand clearly what is meant when we speak of them in the following pages.

LACTIC ACID BACTERIA.

This form of bacteria as seen under a microscope of 1000 x appears in short rods slightly contracted in the middle, as will be seen by the representation below.

It will resist very high temperatures, and it requires at least 250° F. for ten to fifteen minutes to kill the dry forms.

They are the forms which commonly cause milk to turn sour, but are found everywhere in fermenting fruit juices, and act very readily on the milk of corn. The above view was taken of a culture of these germs transferred to a drop of corn milk and placed under a microscope. Their action is directly on the sugar contained in the milk and they convert it into lactic acid with no carbonic acid gas when acting alone. They are rarely if ever found acting alone, however, and it is only by making pure cultures that they may be studied for a short time under the glass. Other forms will make their appearance very soon. This form of bacteria flourishes very rapidly at a temperature of 80° to 90° F. It grows on gelatine plates as small, white points, becoming opaque, forming a thick layer. The colonies appear dark yellow in the middle. This is one of the species of bacteria which are found acting on nearly all kinds of food products and has considerable resisting power to high temperatures.

BUTYRIC ACID BACTERIA.

Clostridium butyricum and amylobacter are the putrefactive ferments which cause a great deal of trouble in the canning indus-

try. This form is one of the most resistant to high temperatures, and develops spores which are hard to kill. These spores are found in dried-up forms clinging to the fresh product, and will begin to develop whenever a suitable medium presents itself.

These bacteria act on the sugar producing butyric acid, carbonic acid and hydrogen, and they are anaerobic, producing a very unpleasant taste in fruit juice. It is a motile organism and looks like a short straight rod. When these bacteria are ready to form spores they swell up into peculiar shapes, spindle, club shape, lemon shape and elliptical. The spores burst the outer protoplasm and begin developing into a new organism. When colored by iodine the butyric bacteria appear blue. They develop rapidly at blood heat. In gelatine they form yellow colored colonies. I consider this form of bacteria to be one of the most dangerous forms to be met with in the canning of corn and peas. The full grown bacillus is easily killed at the boiling temperature, but the spores, especially the dried-up forms that have been floating in the air when they find a lodgment in the milk of the corn, are very hard to kill. They are so small in this dried-up form that we can almost conceive of them being able to pass through the juice without becoming wet. After milk has soured by the action of the lactic bacteria, and the acid is neutralized by lime, it will set up butyric fermentation caused by the butyric ferments. This is a spontaneous butyric fermentation from the bacteria in the atmosphere, and will start at a temperature of 70° to 80° F. The butyric ferments act very readily on starch, dextrine, dextrose and sugar cane. These bacteria also play a very important part in the ripening of cheese and give it its peculiar flavor. They have the power of decomposing fermentable substances without the aid of free oxygen, and on this account we term them anaerobic. The following view will give some idea how they appeared in a view taken of fermenting corn milk. The rods represent the bacilli and the dots represent the spores.

ACETIC ACID BACTERIA.

The two well known forms of bacteria which cause acetic acid are the mycoderma aceti and the bacterium Pasteurianum. In 1838 Turpin and Kutzing discovered that acetic acid fermentation was caused by micro-organisms, and Pasteur in 1864 confirmed the correctness of their assertion and called the organism mycoderma aceti, but as he was not working with any particular culture, he did not bring out the fact that this acid could be produced by at least one other form, if not more. As he did not employ pure cultures,

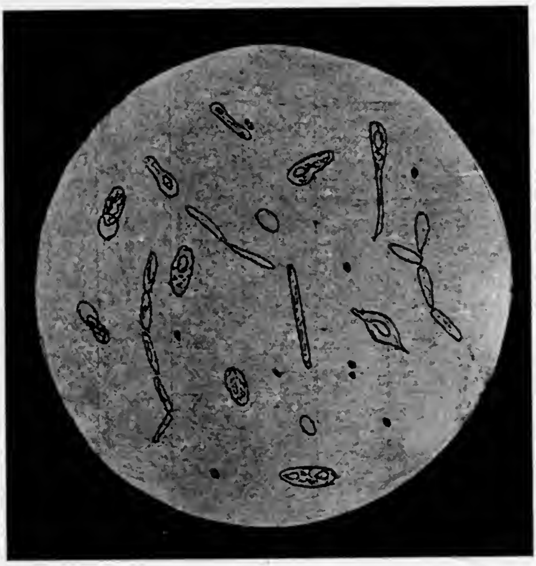


Figure 9.

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BACILLUS BUTYRICUS.

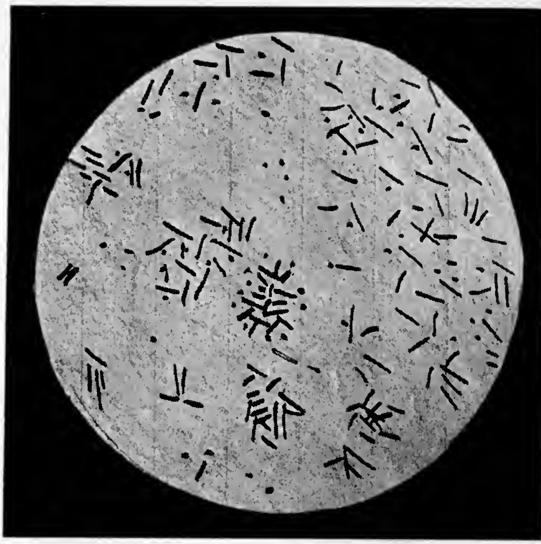

Figure 10.

MAGNIFIED X 1000.

BACILLI BUTYRICI—SHOWING SPORES.

his methods of making vinegar were not used practically, and in 1879 Hansen classified the germs and obtained pure cultures. The "quick vinegar process" is employed in the manufacture, where the liquid is divided into drops and given free access to the atmosphere and given free distribution over large surfaces of beech shavings, where the process is taken up and completed by the organisms. The acetic acid germs are characterized by long chains of hour-glass shape, partially bacilli and curved forms. Mycoderma aceti are stained yellow by iodine, while bacteria Pasteuriana are given a blue color by the same stain. No spores have been seen in these bacteria.

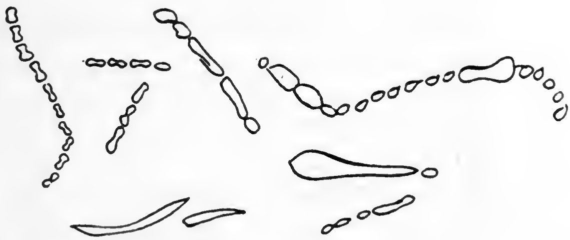

Figure 11.

MYCODERM ACETI AND BACTERIA PASTEURIANA.

The bacteria are present in large numbers in various fruit and vegetable juices, and are so common everywhere in the atmosphere that they are among the earliest forms of organic life to appear in the fermentation of food products.

BACILLUS VISCOSUS

We will now take up the study of a form of bacteria which plays a great part in the spoiling of canned goods, especially of vegetables like peas, beans, asparagus and corn, causing the whole liquid part to become slimy and ropy so that it can be lifted in long sticky threads. The varieties or species of this slime producing bacteria are given the name of bacilli viscosi. They have the power of resisting high temperatures which, of course, makes sterilization difficult.

It is, of course, very necessary to know the characteristics of such forms of bacterial life, their forms, resisting power with reference to heat and antiseptics and their probable source, in order to guard against them as much as possible at the time when the pro-

duct is exposed to their action. You have, no doubt, seen cans of various kinds of vegetables opened and found the liquid part ropy and slimy, when to all appearances it was clear when filled into the can. This trouble has caused the packers of peas no end of worry, because they have not taken into consideration that much of this trouble was due to this kind of a bacterium. There are some people who put up a great deal of molasses in tin cans, and have a great deal of trouble in preventing fermentation, especially during the hot summer months.

The fermentation set up by this organism is very violent, especially when deprived of free oxygen. It forms carbonic acid gas in great pressure, even to the extent of bursting cans tested to withstand 50 to 75 pounds pressure. Bacilli viscosi make slimy patches in molasses and sets up this fermentation, and on account of its resisting power to sterilization, it is hard to keep molasses in tins during the hot weather, because high temperatures deteriorate the quality of the goods.

This organism causes the same trouble in wine and beer, which we sometimes see, become ropy. The organism forms in clusters resembling zoögloea as the envelopment in the slime formation holds them in clusters. Pasteur discovered these bead-like chains which set up a viscous fermentation with carbonic acid gas when introduced in wine and beer, and Van Laer found bacilli in rods forming zoögloea, which produced the same viscous fermentation. This fermentation and slime formation is great in proportion to the quantity of nitrogenous matter in the liquid. Ordinarily the cocci appear in pairs surrounded by an envelope of mucilaginous matter. They sometimes grow without the gelatinous envelope, and so appear when cultivated on potato.

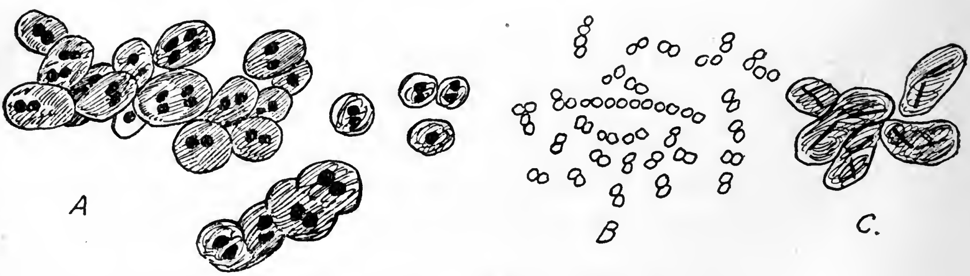

Figure 12.

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BACILLI VISCOSI.

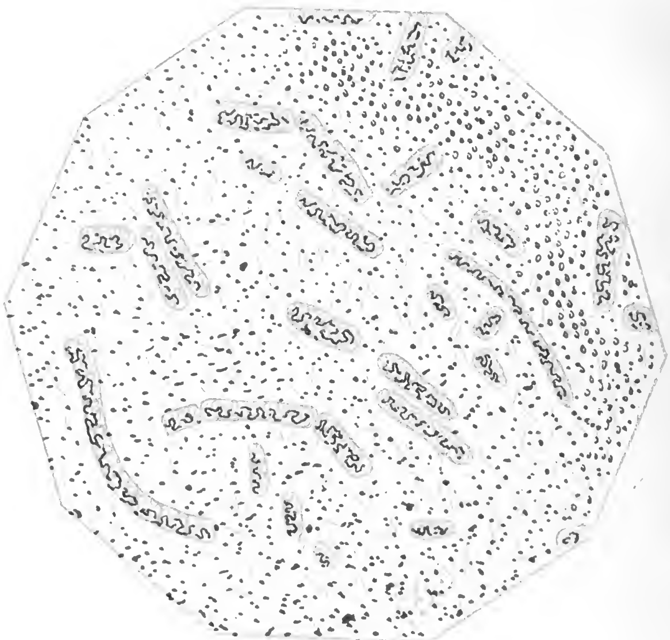

Figure 13

MAGNIFIED X 1000.

ONE PART BOUILLON, 99 PARTS WATER. RANK PUTREFACTION, BOUILLON, PRODIGIOSI.

The manner of protecting food products from this scavenger and the requirements necessary for sterilizing vegetable and fluids where it finds a lodgment, will be taken up under the process employed in canning and preserving as they will be described in pages to follow, and under those heads we will endeavor to clear up some of the mysteries of spoilage.

BACILLUS PRODIGIOSUS.

This is the organism which gives the odor of herring brine or fish to putrefying substances, and is also named bleeding bread, because it is a pigment bearing bacillus of red color, and forms spots when growing on bread, potatoes and onion that resemble blood. It is an egg-shaped germ about $\frac{1}{25000}$ of an inch in diameter, which is very small. It has no motion and multiplies by division. It is so minute as to be barely perceptible with a power of 1000 diameters, and Ehrenberg calculated that a cubic inch would contain one quadrillion. This organism is very common, nearly always associated with decomposition of vegetable matter in putrefactive stages. One peculiarity about this bacillus is that at blood heat it fails to produce the red pigment and peculiar fish odor, but at 60° to 70° F., when cultivated on agar, both of these characteristics are evident. The drawing here represented was taken from life.

Prodigiosus has the property of converting fermenting substances of a fermentable nature into lactic acid at a temperature of 80° to 90° F., at which temperature it produces no red pigment, so that the whole of its energy is employed in the fermenting process. When milk is soured and lactic acid is produced, it sometimes has a blue color, which is a pigment in the protoplasm of a bacterium, similar in many respects to the bacillus prodigiosus. Bacillus prodigiosus is also a germ causing unsoundness in bread and bakers have to guard their dough against this action to prevent souring before the baking. In manufacturing tomato catsup and various condiments where chopped onions are used, it is advisable to keep them in cool places or use them as soon after chopping as possible, to avoid discoloration and flavor injury from the action of this bacterium.

SACCHAROMYCES APICULATUS.

This is a lemon-shaped bacterium and is one of the few germs which have a peculiar form easily recognized wherever we meet them. They always appear on the juice of sweet juicy fruits when exposed

to the atmosphere. The buds are either lemon shaped or round. The first view I had of these peculiar forms of organic life was on a substratum of pineapple juice to which had been added a small quantity of sugar, and left exposed to the atmosphere. In a short time a fermentation set in which was not unpleasant to the taste. Examination under the microscope revealed a pure culture of these bacteria, and the scene was one of the prettiest I have ever examined. The little lemon-shaped cells were sending out buds rapidly, and the juice had a flavor of alcohol so similar in many respects to the yeast plant fermentations, but its power to produce alcohol is only about one-sixth of that produced by the yeast saccharomyces cerevisiae. It is found in abundance during fruit seasons on cherries, grapes, plums, gooseberries, pineapples, etc., on the ripe fruits, ready to begin action as soon as the juice is exposed. It is always found in the soil under the trees and bushes of such fruits, probably on account of having flourished on fallen fruit and carried down into the ground by rains; remaining alive all through the winter. In the summer time it is carried by wind or dust, and falling upon the fruit still growing, remains until it ripens before setting up fermentation. This characteristic ferment to this kind of fruits, its habits, its habitation, and last its lodgment on the fruit which makes its existence possible, is only an example of almost every other form. Each form will be found in close proximity to its victim, and nearly all fruits and vegetables and other things will have the dried-up forms either on them or near them, ready when the time comes to resolve the substance again to elementary forms. This is the great scheme of nature to make old things new again, and reduce the matured things of earth to elements to furnish nutriment for the new.

Although there are many other bacteria which make their appearance in fermentable substances, we have described a few of the more important as having to do with the canning and preserving industries, and they are the principal forms we meet, and if we guard against them, we need have no fears about other forms, excepting, perchance, a bacterium like the bacillus subtilis and the bacillus panificans should make their appearance, in which case the entire method of canning would have to be changed in order to keep the goods from fermenting. So resistant to heat are the spores of these two forms, and I have no doubt other unclassified forms, that they can withstand temperatures of 300° F. for hours, and then develop and cause fermentation. So far as I know, these forms have not made their appearance in articles or products which are canned

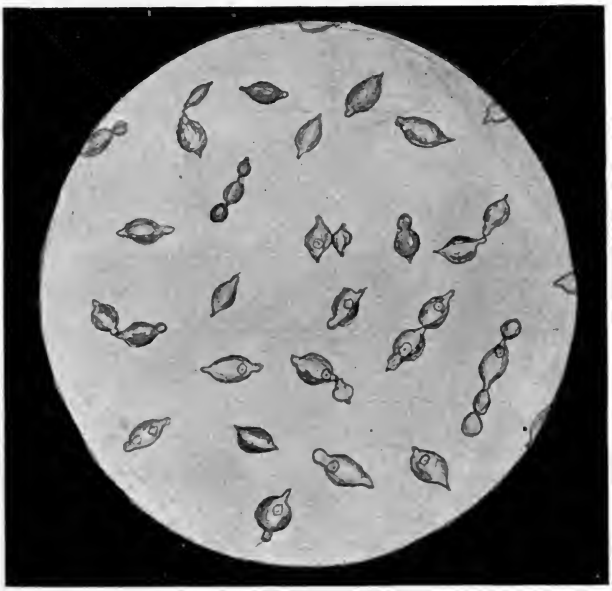

Figure 14

MAGNIFIED X 1000.

SACCHAROMYCES APICULATUS ON PINEAPPLE JUICE.

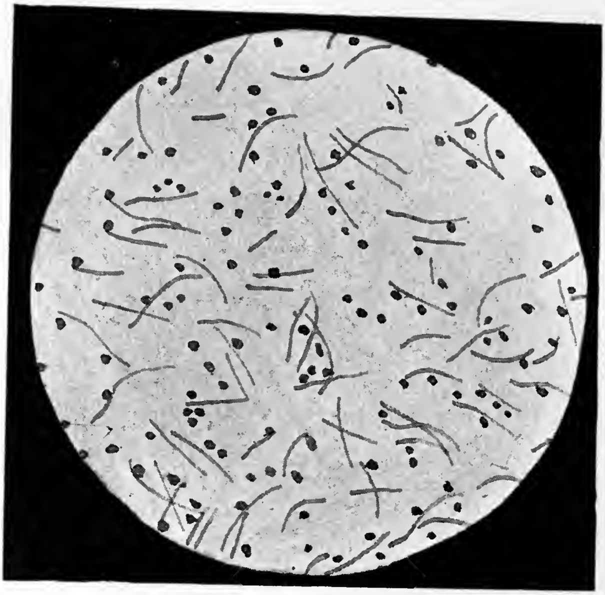

Figure 15.

MAGNIFIED X 1000.

BACILLUS SUBTILIS WITH ENDOSPORES X 1000 ON BOUILLON.

and preserved. It might be well, however, to give a sketch of these two forms, for fear, perhaps, they might at no distant time find a place among the scavengers of canning products.

BACILLUS SUBLILIS.

This bacillus is spore bearing, and the spores appear to be special protoplasmic cells, developed in the parent, surrounded by a thin but very hard membrane, and it is this membrane which protects the life of the spore against the action of heat and antiseptics before development into full grown bacilli. Dry heat, of course, would be less efficacious than moist heat, because the latter if applied in certain ways will soften the membrane and cause the protoplasm within to swell, at which time the germ is most susceptible to high temperatures. When moist heat is applied it is noticed that the protoplasm becomes dark and granular, where before it was clear and transparent, and it then begins to swell and gradually will stretch the membrane until it bursts across the middle, which distinguishes this form from the bacillus amylobacter, which bursts its membrane lengthwise. After bursting the membrane it makes its way out and begins to vegetate by lengthening and dividing across the rod form, at which time heat of 160° F. will kill them. This bacterium makes its appearance in hay infusions that have been boiled, and it is the organism that caused Professor Tyndall so much trouble in trying to sterilize the infusions on account of its great resisting power to heat. It is a motile organism about $\frac{6}{25000}$ of an inch long and $\frac{2}{25000}$ of an inch in diameter. Its spores are large and easily studied. It multiplies very fast, producing much carbonic acid gas and seems to be peculiar to hay.

Owing at times to the close proximity of hay fields to land where the cultivation of canning products is carried on, it would not surprise me at any time to find this organism flourishing in corn, peas, beans, etc., in which case a complete change of processing would become necessary in order to keep these articles from fermenting. In that case the present sterilizing process would be useless, and new methods based entirely on bacteriological knowledge would have to take their place. The system referred to will be taken up in detail under another head, and people who desire to be progressive can find a method laid down to form the base of experiments that ultimately will insure a superior quality and perfect sterilization.

The bacillus panificans is another spore-bearing bacillus which

is very resistant to the action of high temperatures. The bacilli themselves, like the bacilli subtilis and butyrici, are easily killed at less than boiling temperature, 212° F., but the seed form, the spores, are very resistant and cannot be killed by continuous boiling, notwithstandng any statement made to the contrary. These statements are made by some scientists who claim to have killed the spores in half an hour by boiling, but they either were dealing with other forms or kinds of bacteria, or they never did what they claimed. We know that Tyndall tried this, and we have his word to the contrary, and our own experience with corn and peas, etc., bears him out. I have tried time after time to kill these forms by boiling for eight hours, and every experiment broke down. So the spores of panificans cannot be killed by boiling. This is the organism which sets up the fermentation of the dough of rye bread, and is peculiar to rye. It is a short motile rod with threads which interlace to form a film when grown on liquid media. So far as I know these two forms, subtilis and panificans, do not as yet enter into the catalogue of ferments, which cause the troubles in canning and preserving of food products.

CHAPTER V.

PATHOGENIC BACTERIA. STUDIED BECAUSE OF THE POISONS PRODUCED WHEN ACTING ON FOOD PRODUCTS. DIFFERENT KINDS OF THESE BACTERIA STUDIED. THEIR ACTION ON VARIOUS FOOD PRODUCTS DESCRIBED.

We have been describing bacteria of non-pathogenic character, viz: The ordinary forms and organisms which cause fermentation of food products, but which have no connection with the diseases of man. While it is true that ordinary ferments when causing fermentation, if taken into the stomach, will cause stomach disorders, and sometimes violent sickness, they must not, however, be conflicted with organisms which cause specific diseases in man. It is not our purpose in a work of this character to take up a complete history of all known forms of diseases and the organisms which cause them, but simply to study those forms which in atmospheric fermentation find a lodgment in food products of albuminous nature, and by their action on the albumens produce alkaloids and toxic poisons which come under the generic name of ptomaines.

In a preceding chapter (page 21) we have taken up the subject of ptomaines and called attention to the very common occur-

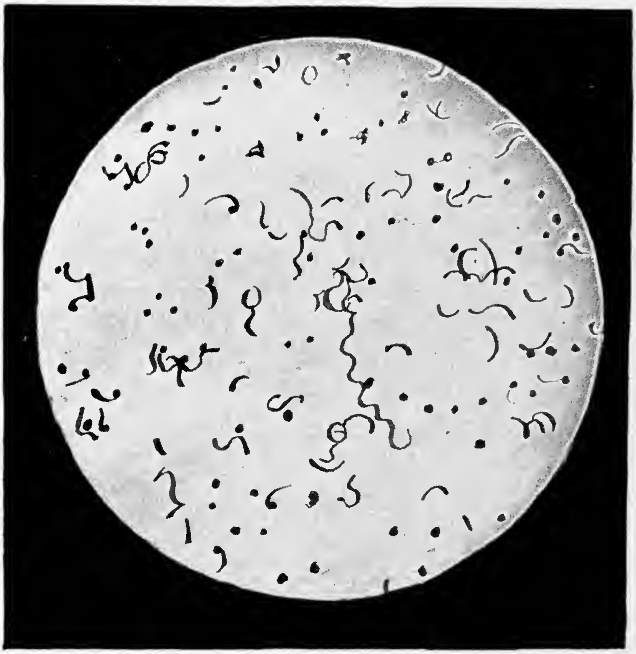

Figure 16.

MAGNIFIED X 1000.

CHOLERA GERMS IN COMMA, S SHAPED AND O SHAPED FORMS.

rence of poisoning from these alkaloids, and a description of some of the organisms must be interesting. The study of these forms carries the student in bacteriology into a very difficult field, from the fact that the character of these organisms, their mode of action, etc., is removed from the ordinary field of fermentation, and while their action is fermentative in character, they are so frequently found deep in the tissue of the muscles of the sufferer that they become anaerobic in nature, and hard to cultivate in an aerobic state on mediums prepared by artificial means.

Many forms, however, occur so abundantly in nature that they can be cultured and studied, and these forms, with possibly one or two exceptions, fall into the line of our study here.

COMMA BACCILLUS—CHOLORA.

The ptomaines, cadaverine, putrescine and choline are without doubt the result of this deadly germ, which has started a fermentation on albuminoids. The comma bacillus was discovered by Dr. Koch to be the cause of Asiatic cholera, and it is due to this brilliant scientist that the mysteries, doubts and difficulties surrounding this dreaded pestilence have been cleared up. It was proved that the germs were carried in railways, caravans and ships from Lower Bengal in the delta of the Ganges to all parts of the world, although this organism is, no doubt, present in every section of the globe. It does not, however, break out into epidemics like those occurring in Asia, except in very rare cases. The section of country mentioned is the regular hot bed for the disease, and it is epidemic there frequently, owing, no doubt, to imperfect sanitary measures.

The comma bacillus belongs to the class of spirilla, or curved bacteria, and usually occurs in slightly curved rods measuring from 1 μ to 2 μ of an inch in length and about .5 μ of an inch in thickness. It occurs sometimes in pairs, sometimes in the shape of letter S. Frequently they assume the shape of serpentine threads. The bacillus is identified by placing some of the substance on which they grow on the glass slide under the microscope and allowing a weak solution, methyl violet, to flow between the cover glass and slide, taking up the overflow by blotting paper. With an oil immersion lens of 1000 diameters they may be observed alive.

They may be easily recognized by their vigorous movement and the stain from the color which they take up. They will grow and multiply rapidly on prepared meat broth kept at blood heat in an incubator, and in time grow larger and form spirilla.

Chemical examination and analyses of this broth will show the presence of the ptomaine poisons mentioned at the beginning of this section. Babes found that at a temperature of blood heat, the bacillus would grow on various kinds of meat, on eggs, vegetables and moistened bread, on cheese, coffee, chocolate and fluid sugars, but only feebly on acid fluids or vegetables, on mustard, onions, wine, beer or distilled water. Wherever there is a large quantity of organic matters, as at the margin of stagnant water, they would thrive. Milk is one of the most dangerous agencies for the growth of the bacilli, and has caused the death of many persons who have used it.

The comma bacillus is an aerobic organism, but does not cease to multiply if the supply of oxygen is cut off, but may under this condition be killed readily by germicidal agencies, while in the aerobic state they are very resistant to such agencies. But when the supply of oxygen is cut off it produces a much larger proportion of toxic poisons than when oxygen is present, on account of the necessity of acting on a much larger quantity of albuminous matter in order to get the oxygen necessary to its reproduction.

One fact relating to this organism, as well as all other organisms we have been considering, is that freezing does not kill them as they seem to pass through a dormant state, and will develop on a suitable medium at favorable temperatures. One experiment by Koch on these bacilli at —10° C. did not kill them, and they developed rapidly when placed in favorable conditions. The early observations on ptomaines and sepsines, Pasteur's and Hansen's later observations, led to a search for finding the poisonous properties, or rather results of the action of comma bacilli. Koch prepared cultures of these organisms which were very poisonous, and when given to animals in any way caused their death—"paralytic weakness of the lower extremities, coldness of head and legs and prolonged respiration, leading to death." Pouchet and Villiers were able to obtain substances from the action of the comma bacilli on the dejecta and organs of cholera patients which were characteristic of the organism.

Pouchet used chloroform and extracted an extremely toxic poison in the nature of an oily fluid which changed colors in the presence of light and air. His substance gave the characteristic reaction of the alkaloid, the blue reduction color with ferrocyanide and perchloride of iron. Villiers also separated an alkaloid from the dejecta of a cholera patient which, when treated with muriatic acid, formed crystals, which, when chemically combined with other com-

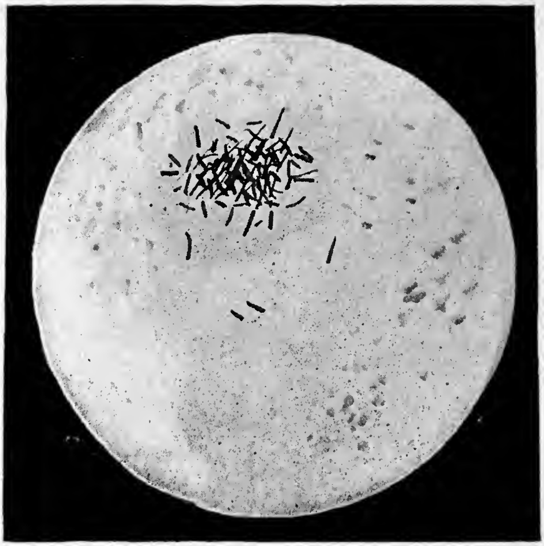

Figure 17.

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TYPHOID BACILLI IN CLUSTER FOUND IN A GLAND IN THE INTESTINES.
FROM REAL MICROSCOPIC VIEW.

pounds, produced a caustic local action and muscular troubles and an irregular heart action, and finally death. Brieger was able to find several poisons, especially from cultures of the bacillus which were old, which were choline, cadaverine and putrescine. He went into these researches very far; he obtained a toxic poison which, when injected into animals, produced muscular tremors, cramps and death. He named this new product methyl-guanidine. He also separated two other toxines characteristic of the cholera bacillus. All these experiments were made with pure cultures of the comma bacillus, and the toxines found were, of course, in much larger proportions than when found in natural growths on suitable media. Experiments with these natural growths, however, give practically the same results, proving that the comma bacillus is capable of producing the most deadly ptomaines.

One peculiar feature in the study of this deadly organism is that it does not exert a rapid fermentation where other common ferments and non-pathogenic putrefactive organisms, have obtained a hold. Indeed, we can state that these other forms would isolate the comma bacillus and cause it to perish, because certain acids would be produced by their action which would act as antiseptics to it, and this is true where almost all other pathogenic forms appear outside of the body. Once in a while, however, under favorable conditions, it happens that the cholera germ will begin action first and produce a ptomaine before other common forms would get a hold on the product. In this case, should the substance happen to be a food product of an albuminous nature and taken into the stomach at any time after the organism had produced the toxic alkaloid, serious muscular tremors and cramps would result, perhaps ending in death.

TYPHOID BACILLUS.

The typhoid fever germ when growing in meat broth and albuminoids produces a ptomaine which has been isolated by Brieger and called typhotoxin, and it is on this account that we take up the study of this organism. The bacilli are short, thick rods from $\frac{2}{25000}$ to $\frac{3}{25000}$ of an inch in length and about one-fourth of their length in thickness. They have slightly rounded ends, and the protoplasm is susceptible to color by aniline dyes. They also may be stained by allowing them to stand in a solution of oxalic acid, and after washing will take a methyl blue color. The typhoid germ is found in the kidneys, spleen and intestines of fever patients, in colonies or clusters widely separated, which sometimes makes them

difficult to locate. Cultivated they assume a thread-like appearance, with flagella, which gives them a wavy motion. The germ is able to flourish in either an aerobic or anaerobic state, exhibiting the same peculiarities as the comma bacilli, in that, when growing in the presence of oxygen they are very resistant to the action of germicides and heat, and produce less toxic poison than when growing in an anaerobic state, requiring the decomposition of more albuminous substance to obtain enough oxygen for their multiplication.

The typhoid bacilli grows rapidly on potato, where they assume typical forms, because the potato is slightly acid, which is a necessary characteristic for their propagation.

Unlike many other forms, this germ seems to form an acid poison instead of an alkaloid poison. It develops rapidly in milk and also in water containing decaying albuminous matter. When cultures of this bacillus were given to animals in food they soon died, but was found that the bacteria need not be alive to cause death. Any substance which had been exposed to their action would also cause death when reaching the intestines, and the cause was traced to toxic and ptomaine poisoning which Brieger proved were present in the substances.

These organisms are visibly affected by light and grow best in dark or shady places. Rays of sunlight or chemical rays are very injurious to their development. This is true of nearly all pathogenic forms, and it would seem to indicate that the rays of light seem to shoot them, to use a military term, and it is hoped that the development and improvement of the X-rays will begin to open up a new method of destroying these dreadful enemies of man. It is a dreadful thing to contemplate, that there are organisms so minutely formed which can find their way into the body and use the tissue to build up poisons so fatal. We can now see that it is not so much the germ itself which causes the death of man as it is the poison deposited by the germ deep in the tissue which paralyzes the muscles and stops the heart from beating.

These organisms also build up the same poisons in the very food we eat when proper conditions present themselves, and were it not for the fact that man is fortified against them, by counteracting influences and secretions of the body, we would all fall victims one by one to their deadly action. Nor can we say that we will escape finally, but so long as we know the enemies and can take proper precautions against them, by removing from our midst those decaying things on which they grow, eat and drink pure

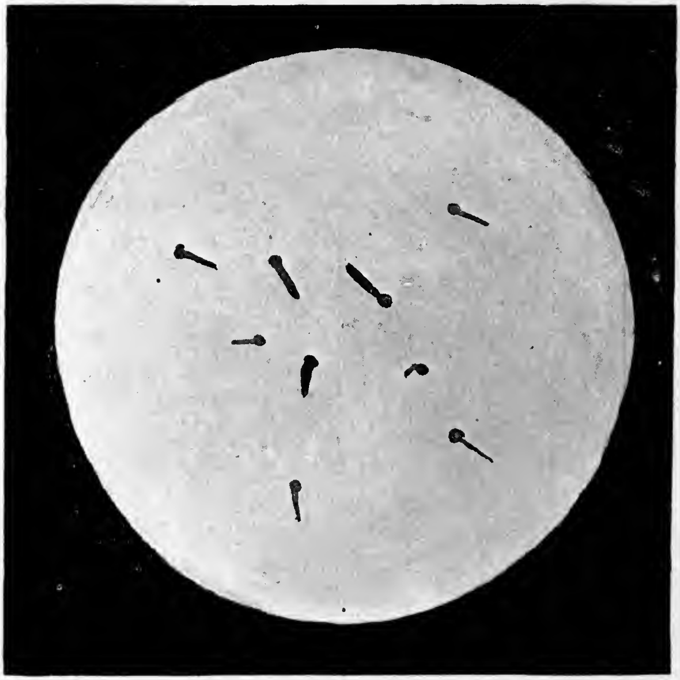

Figure 18.

MAGNIFIED X 1000.

TETANUS BACILLI.

food and water, observing every sanitary rule, we can at least keep the enemy in check until age has weakened our energies and we finally have to face the inevitable. Like the plant and the beast, nature will claim us all, our bodies will form the food for this insignificant germ and we will pass away to be dissolved again into elementary forms.

What a study it is then, this science of bacteriology. It opens up a new world to us and we are permitted to gaze upon it and behold the scheme of nature giving us object lessons day by day in the tearing down and building up process. Life begetting new life, and new life flourishes on the dead. Seed developing into form, form producing seed, decay of form, and development of seed. This is true of the germ and also of every living thing.

TETANUS.

The tetanus bacillus produces specific poisons which have been found and isolated, viz: tetanine, tetanotoxin and two other alkaloids resembling strychnine.

Tetanus is an infective disease, a wound fever, and known as lockjaw, and is produced by a micro-organism which finds its way into a wound and sets up a muscular disease by producing poisonous alkaloids. This organism is found in the pus of the abscess and in the surrounding tissue. It is a thread shape bacillus with slightly rounded ends. The spores are formed at the end of a short rod and develop at blood temperature after thirty hours. When the spores form on these short rods, which are motile, the bacillus resembles a drum stick. It is a strongly anaerobic organism, as the presence of oxygen interferes with its development, and this fact has made it a difficult matter to obtain pure cultures. Cultivations are made, however, in an atmosphere of hydrogen.

Brieger, to whom we owe much of our knowledge of the toxines and ptomaines, which are the poisonous alkaloids produced by the pathogenic organisms, found the poisons peculiar to this germ, which he describes as tetanine and tetanotoxin. From the fact that this is an anaerobic organism it is surprising on first thought how it could gain a hold in a wound where oxygen, of course, is present, but when the spores of this organism find a lodgment in a wound, where proper precautions have not been taken, the pus and blood corpuscles soon cover them and cut off the oxygen of the air. Here then the conditions are favorable for the development of the tetanus bacillus. Tetanus bacilli, or more properly their spores, are very common and are found everywhere,

in the soil and around horses, particularly. They seem to be found more numerously around stables, in manure and the soil which has been manured. Vaillard and Vincent made careful observations of the results of the tetanus bacillus, and having separated the poison, found that it acted very similar to snake poison. They found that the bacilli did not produce poison only after acting for quite a time. In the presence of other organisms of putrefactive nature, such as lactic acid bacilli and prodigiosi, they produce the poison much more quickly. This peculiarity of the organism is a striking contrast to the other forms we have been considering, because the acids of the common putrefactive organisms usually have a germicidal action on pathogenic forms. Even small quantities of this poison if present in any food will set up the most terrible muscular tremors and cramps, followed by sure death, as there is no known antidote. It is a peculiar fact, however, that we are fortified to some extent against this organism before the poison is formed in the wound; the blood corpuscles in healthy tissue generally destroy it. This organism then is dangerous to man if it happens to find a lodgment in any food product, especially in canned meats and goods of an albuminous nature, where the packages are sealed hermetically, producing anaerobic condition so favorable for its reproduction, and also from the fact that it is able to produce ptomaines more rapidly when acting along with other putrefactive micro-organisms.

Stanley in his travels through Africa gives a bit of peculiar and interesting information which we can readily trace to the action of this organism. He found that the savages in certain sections poisoned their arrow points by covering them first with a nutrient juice of a tree, then taking them to a place where drainage had accumulated decomposing substances, they stuck them in the soil, allowing them to remain for a considerable time. These arrows would set up the most violent muscular contractions, followed by lockjaw and death whenever they found a lodgment in the flesh of their enemies. This poison was, no doubt, caused by the formation of an alkaloid poison by the tetanus bacilli.

We are of the opinion that poisons in food products from this peculiar organism do not generally occur in foods that are exposed to the air, but only in hermetically sealed packages. We frequently hear of some one being poisoned, sometimes whole families stricken after having eaten certain kinds of canned meats, and we feel assured that this organism produces some of the poisons which cause these complications. It is likely that its action takes place after

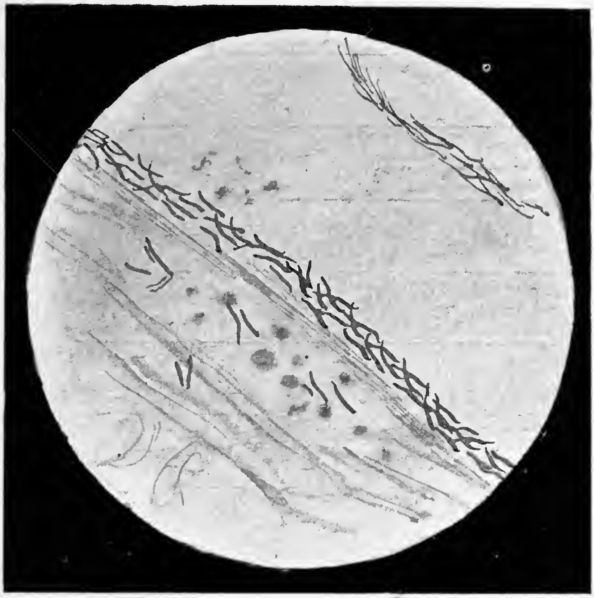

Figure 19.

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KLEBS-LOEFFLER BACILLI X 1000.

the can has been sealed, before the final sterilizing process, which destroys their life, but not the product of that life. This trouble is due to carelessness, the result of ignorance of the deadly nature of these organisms, and this carelessness is the allowing of too much goods to pile up ahead of the final process.

KLEBS-LOEFFLER BACILLUS—DIPHTHERIA.

The diphtheria, or Klebs-Loeffler bacillus, when growing on suitable media, produces a most virulent ptomaine, which Brieger isolated and used in various experiments upon animals, which caused a poisoning similar to septic, phosphorous and metallic poison. On this account, many cases of poisoning from eating substances like ice cream and certain kinds of meat, fish, etc. (which were due to a ptomaine, where the action resembled metallic poisoning), were at first thought to come from the metal packages which contained the foods. As a matter of fact, however, the agent was a bacillus similar, if not identical with the Klebs-Loeffler bacillus. The suspected metals are not so poisonous as many persons imagine, as they are found in many vegetables. Copper is found in the tomato in some sections, and other vegetables contain metals also. One eminent authority has gone so far as to state that the system is not affected by the presence of metals in small quantities in food products. The poison that does cause the trouble in these food products is an alkaloid produced by micro-organisms, such as the diphtheria bacillus. That this organism produces a most virulent poison is undisputed from the fact that the fatality from the specific disease is very great. As has been stated in former pages the chances of these pathogenic forms, for acting on food products, are very rare in comparison to the action of common ferments, but occasionally they get a start, and when they do, we are informed of the fact by the terrible consequences produced on the innocent victims. It is only as a word of warning to packers and preservers that we have taken up this subject, to point out where the danger exists, and to make a few suggestions, which may by careful observation, preclude the possibility of these cases of poisoning in the canning business, where even a few cases of this kind causes opposition and prejudice against canned goods generally. Whenever a case of this kind occurs it hurts the entire business, and we must take unusual precautions to guard against them. But to return to our subject, the Klebs-Loeffler bacilli are rods from 3 μ to 6 μ of an inch in length, slightly swollen at one or both ends, and are colored easily with methyl blue, or by Gram's gentian violet method.

It is recognized from other bacilli, which may be present, by the deep stain which it takes in contrast to the lighter stains taken by other forms. It is a difficult organism to cultivate in a pure form, as other putrefactive ferments get started first and overgrow the media. It thrives at a very high temperature, and the spore forms will live in the air and on the clothing for a long time. It produces an alkaline poison which loses toxic properties when made acid, and gains back the properties when made alkaline again. Milk is susceptible to the action of this germ, also any food of an albuminous nature, but the toxic power is lost in the presence of the common ferments, which nearly always gain a foothold first and produce their acids, which have a tendency to neutralize the ptomaine which it produces.

It must not be understood that the varieties we have mentioned in the foregoing sketches of pathogenic organisms include all the kinds that produce ptomaines. It is undoubtedly true of many others, among which we might mention the anthrax bacilli and organisms which cause septicaemia, but the products of all these forms are very similar in their action, producing severe muscular contractions, cramps, paralysis and death. By studying their nature we may to some extent understand the life history of these forms and the poisons which they create by their action on food products. It is this knowledge which will enable us to pack and preserve food products and eliminate these forms so that no poisons will be deposited in them. It is a very fortunate thing that their action is confined to food products of an albuminous nature, as this represents only a small proportion of our business. The greater number of packers and preservers confine their preserving to vegetables and fruits, while the greater bulk of albuminous products are packed by comparatively few canners. We refer here to packers of beef, fish, oysters, lobsters and soups, and it is to these packers that the history of the ptomaines as here detailed should be very interesting and instructive. The greatest danger in all these varieties comes in warm weather, when the thermometer ranges about blood heat. These products when exposed for only a very short time to the atmosphere offer the most suitable medium for the propagation of putrefactive ferments of all kinds, including, of course, the pathogenic organisms. It is a peculiar fact that the most favorable time for these organisms to gain a foothold is after the first cooking, because it so rapidly develops the spores, or dried-up forms which may find a lodgment there. The heat, of course, is the reason for this and the anaerobic forms will develop rapidly

after the cans are sealed if they be not taken immediately to the final process for sterilization. Once more we must sound the warning that all goods, whether vegetable or albuminous in character, should find their way immediately to the retorts after the first heating. Here is where the greatest trouble to all packers occurs; something breaks down about the machinery and the consequence is that many dozens of cans will pile up which have within them the spores of germs deposited from the air or perhaps clinging to the product from the beginning. At so favorable a temperature for the development of these spores, a delay for only a short time is inimical to the quality. Fermentation begins to set in almost immediately, and the most wonderful growths of bacterial forms can take place in a very short time, which will change the very nature of the goods, producing new chemical combinations and sometimes very poisonous combinations, as we have seen. We do not pretend to say that this is the only place where ptomaines could be formed in the albuminous products, but it is one of the most dangerous places. A great deal depends on the management, that when breakdowns occur, other means of taking care of the goods should be provided at once. It is not policy to limit a business to the exact number of machines necessary to do the work when everything runs smoothly, but to be prepared for emergencies of this kind, which always happen, even in the best managed business, by having one or two extra machines which can be utilized at such times.

We can see where great dangers from ptomaine poisoning might present themselves at earlier stages in the canning process. The canner should be provided with experienced and cautious men, and by that I mean men who have studied up on the subject which we are here presenting. The diseases peculiar to the animals and fish, the meats of which are canned, may deposit ptomaines in the living tissue, as we often read of as occurring in cattle, fowls, pork, etc. The Government understands the full gravity of this question by having inspectors for all meats appointed in different cities. If diseased animals should be slaughtered and the meat of those animals find its way into cans, the possibility of ptomaine poisoning among the consumers of such goods would be great. To the personal knowledge of the writer, schemes have been imposed on the inspectors and meat has been canned which was wholly unfit for food purposes. This was done simply with the one idea to save the cost of the meat, while probably the fearful results were never suspected. Packers who are engaged in canning products of an albuminous nature should be very careful that they are entirely

free from anything that would resemble disease in any form. No amount of cooking or pickling will counteract the effect of this poison, it remains because it is a new chemical compound, an alkaloid or an acid. We see the effect of this poison by frequent accounts of persons who have eaten smoked fish, mainly halibut and sturgeon, and also fresh sausage which have become poisoned by pathogenic micro-organisms.

This subject of ptomaine poisoning is a very recent discovery, and its full import has not been felt until within the last few years, owing, perhaps, to the large increase in the mortality of persons using products sealed in hermetical packages. The number of deaths has increased in proportion to the increased packing of goods of this character, and it is with the hope of reducing this mortality that these researches have been given in such minute detail.

CHAPTER VI.

FERMENTATION. OBJECT OF STUDY IS TO PREVENT. ALCOHOLIC FERMENTATION AND THE GERMS WHICH CAUSE IT. PUTREFACTION. DISEASE FERMENTATION. PRODUCTS OF FERMDNTATION. DESCRIPTIVE EXAMPLES. ENZYMES. LACTIC FERMENTATION. BENEFITS TO PLANT AND ANIMAL LIFE. FERMENTATION DEFINED IN A BROAD SENSE.

In order to understand definitely the action of micro-organisms, their life history, functions and products, we must take up the subject of fermentation, not with the same object, however, as brewers and wine makers, but with a view of counteracting the process. The canning and preserving industries are established for the sole purpose of keeping food products in a perfectly sterile and healthful condition for food purposes. Alcoholic fermentation is the kind which is set up by the saccharomyces or yeast plants, of which there are a great variety, but only a few kinds are used in the brewing business, mainly those which produce the greatest amount of alcohol. Then there is the putrefactive fermentation, caused by various kinds of organisms, chiefly of a lower form than the saccharomyces, and it is their organisms which reduce the decomposing animal and vegetable matter into elementary forms.

Then there is the disease fermentation which is set up in the living tissues of man and animals by the pathogenic organisms, and they deposit poisons which produce various diseases and death.

Taken as a whole, fermentation is the breaking down process, a reduction of the higher forms of life to elementary forms. When a fermentable substance is exposed to the atmosphere it is seized upon immediately by various organisms. These are deposited in dried-up forms, called spores. These spores are seeds just like a grain of corn is a seed of the full-grown stalk, and they will develop by vegetation into their normal condition and will bear again the same kind of spores or seed. There are some organisms, however, which do not bear spores, but which multiply by division, simply lengthening out and dividing in two, while the life principle seems to be contained in the cell walls, which, in a vegetating state, are swelled or distended and filled with a protoplasm to which has been given the name plasma.

Now when these spores find their way into our fermentable medium they do not all begin to vegetate, but only those forms which have an affinity for that particular medium, of which there may be quite a number of different varieties. They may not all begin vegetating at once, we may have an alcoholic fermentation set up first, which means that if the medium is suitable for that particular fermentation, the sugar will be broken up into alcohol, carbonic acid gas, glycerine, succinic acid, etc. After this the alcohol may be seized upon by other forms, such as acetic acid bacteria, which will convert it into acetic acid. Again the butyric and lactic ferments may begin their action directly on the sugar and convert it into butyric and lactic acids. We now have the nature of our nutrient medium entirely changed, chemical changes have been made, the atoms of one set of molecules have gone to make up new molecules, and old molecules deprived of part of their atomical structure form new compounds, similar in many respects symbollically, but entirely different in character. To demonstrate what we mean by fermentation we will take an example which will instruct us by its simplicity. If we take a great number of blocks of wood, such as a child uses for building houses, and we erect a tall, square pile, we will have something of definite shape which we can call by a single name such as a house or a wall. Now if we pull out from the bottom one or two blocks, we change the center of gravity and we have some of the upper blocks standing in a weakened position. Their power of holding together has become less. We can compare the starting of fermentation to the nutrient medium, the same as the weakening influence given to the pile of blocks by the removal of the two at the base. If we pull out another block we may observe the pile begin to waver, and by the removal of another one

whole corner falls. This example will demonstrate the action of the organisms on one part of our medium. Now if we remove from another part of our pile still other blocks we will soon have the whole thing lying in ruins. With our nutrient medium other organisms will take up the work of destruction where the first ones left off, and soon the whole combination will be upset. As one writer has given another example to explain fermentation, we will take the liberty of using the same here. It is a well known fact that the great explosive power of nitroglycerine is due to the unstableness of its atomical arrangement. Some oxygen has been induced to unite with nitrogen, a substance for which under ordinary circumstances it has little affinity, it having at the same time a much stronger affinity for both carbon and hydrogen than these have for each other; rapid and extensive oscillations are constantly going on, the slightest increase of which must be followed by a new arrangement of molecules. A shock so increases these oscillations that the molecular equilibrium is disturbed, the weak bands between the oxygen and nitrogen are severed and the free oxygen is immediately pounced upon by the carbon and the hydrogen, which are set free from one another, each of these elements taking up a certain quantity of the freed oxygen; the atoms of nitrogen having, of course, a strong affinity for one another, combine and a small portion of oxygen is set free. The amount of energy released is very great indeed, and it is the more readily observed and even measured from the fact that the process goes on rapidly and violently, as it usually does where the resolution is that of a very complex body, into extremely simple substances. Now let us see what takes place when sugar is converted into alcohol and carbonic acid gas. When the yeast plant begins to act or set up fermentation we notice an immediate gradual increase of temperature, which may be likened to the tap that caused the nitroglycerine to explode, the molecules are set to oscillating by the temperature and the heat also brings about the proper temperature for the perfect vegetation of the cells, and it is a deduction from what we have seen, that heat and moisture are very necessary in the process of fermentation. These two conditions must be always present, one without the other will not give the result. Pasteur says: "Fermentation, properly so-called, can be looked upon as a chemical phenomenon, corelative with physiological actions of a peculiar nature, in this sense, that bacteria have the property of exercising all the functions of their life, not excepting negative multiplication without necessarily employing the oxygen of the air. Guided by all these facts, I have

been gradually led to look upon fermentation as a necessary consequence or manifestation of life when that life takes place without the direct combustion due to free oxygen." Thus we are brought face to face with one great fact; that is, that not only are bacteria able to cause the fermentation of sugar and setting free carbonic acid gas, but fruits, vegetables, grain, etc., have the same property, possessing within themselves the power to cause the fermentation of the natural sugar present in them, and sugar which may be introduced. We thus see that the process is brought about by living cells, and the kind of fermentation set up depends, of course, on the nature of these cells and also on the nature of the fermentable substance. The yeast plants or saccharomyces have the power, when acting on sugar, to produce alcohol, carbonic acid gas, with other substances, viz: succinic acid, glycerine, etc., which vary in proportion to the kind of substance that these organisms are causing to ferment. Various flavors are also imparted to the different fermentable substances; for instance, the flavor which is imparted to the beer and wine, and the peculiar flavor of cheese and butter we know is due to the products of the butyric ferment, amylobacter. It will not be necessary for us in this work to take up the study of any particular yeast fungus, or to classify these forms, as that is interesting only in the industries of wine and beer making. There have been various works which have taken up the study of the various saccharomyces, and these works are used by brewers and wine makers with an object entirely different from our object, as they need pure cultures of these organisms in their business, while our object is to eliminate, not only these forms, but all others. As a matter of fact the saccharomyces cause the canner and preserver very little trouble, unless it be in the products before canning. They are very susceptible to heat and perish even in the first cooking. There is one form of fermentation, however, similar in many respects to the fermentation caused by the yeast fungi, which is a constant menace to our business. We refer to that caused by mold. This statement will, no doubt, be a surprise to the canner, because he has always regarded mold as a fungus growth which did not play any part in the destruction of his product. The conidia of mold are the spore formations which develop at the ends, or more properly on the top of the fungi. These spores have, by actual experiment, lived through a temperature of 300° F., dry heat, but have not been able to withstand so high a temperature in moist heat. When these conidia find a lodgment on the surface of media which are slightly acid they will develop and begin to

form the new fungus again, but should they be submerged below the surface of any fluid so that the supply of oxygen from the air is cut off, they will assume a different character entirely from the parent fungus and resemble the saccharomyces in many particulars, causing feeble alcoholic fermentation setting free large quantities of carbon dioxide and multiply by sending out buds, which is so characteristic of the yeast fungi. It has often been noticed that when mold forms on the surface of preserves, jellies and other food products that it does not cause any fermentation of those products when growth is luxuriant, for an examination will disclose the fact that the products are perfectly sweet and free from fermentation. Nor can any other ferment get a hold, unless introduced below the surface. The reason for this is that mold, as we know it and see it, is strongly aerobic organism, requiring vast quantities of oxygen for its development. When once started to grow on the surface it will use up all the free oxygen it requires, and any other ferment which falls from the air on the surface will be deprived of the oxygen necessary for its development, and will lie there merely dormant. Now, when the conditions are changed, the substance shaken up so that the film becomes submerged, thus cutting off its natural supply of oxygen, it will obtain whatever oxygen it requires for its development by breaking up the molecules of sugar. This, no doubt, will be a revelation to people who have stored tomato juice in barrels for making tomato catsup. So long as they remain perfectly quiet in the cellar they would appear all right, but just as soon as they were rolled over, the mold flim would become submerged and fermentation would immediately begin, because the conidia of the mold would be deprived of the oxygen they were obtaining in the air space near the top of the barrel, and would begin to feed on the sugar of the tomato to obtain their supply of oxygen. They begin budding like the saccharomyces and in a short time the amount of carbon-dioxide would be liberated so fast as to cause the barrel to burst.

Pasteur brought to light a peculiar phenomenon connected with fermentation, which is, that if the yeast germs are filtered out of a fermenting liquid, that there remains a product of their action, a substance insoluble in alcohol, which has the peculiar power to carry on the fermentation in the absence of the germs themselves; that this substance would invert saccharose into equal parts of dextrose and levulose, and this substance was termed invertine. This invertine will convert starch into sugar, and thus produce conditions favorable to the cells themselves. Experiments have dem-

onstrated that the cells themselves have little power to convert simple sugar water into its elements. There must be something else present, and we find that nitrogen is necessary, which comes from albuminoids. In other words, a medium must be made nutrient before it can be fermented, and by nutrient I mean that it must contain everything necessary for the development of the organism.

Special forms of fermentation is due to the peculiar bacteria of that fermentation and the nutrient medium must contain all the requirements of those bacteria. I can demonstrate more fully what I mean by this by stating that a given bacterium will produce or bring about certain results in one medium, and in another medium of different character the same organisms will bring about different results. A quotation from Wood conveys the idea perfectly. He says:

"Of still greater interest is the varying manner in which the same organism conducts itself toward different albuminoids. * * * As a general rule, those organisms which liquefy gelatine are able to coagulate milk, and then peptonize casein which has been separated; but some organisms which peptonize gelatine are without action on the milk, and some that are inoperative on gelatine, peptonize milk.

"Very striking is the way in which the same organism conducts itself towards the different albuminoids, gelatine, fibrin, blood serum and egg albumen; another liquefies the gelatine, but cannot peptonize the egg albumen. * * * They must, accordingly, be regarded as specific in their nature, depending on the specific nature of the protoplasm of which they are merely further differentiations."

The product of micro-organisms which peptonizes the medium is termed an enzyme. When gelatine is liquefied or when meat is softened by the action of bacteria, it undergoes the same characteristic changes that take place in the stomach, and we term this action peptonization. They have changed from coagulable albumens to soluble albuminoids and in this state are easily decomposed either by the cell protoplasm or the animal secretions. This peptonization is accomplished by what we may term an enzyme, which is the product of bacterial life, especially those belonging to putrefaction.

The butyric ferment amylobacter produces an enzyme which accomplishes the butyric fermentation of vegetable and fruit acids, the ripening of cheese. This enzyme acts on cellulose, then dextrose and glucose, softens the fibre and solid portions of any substratum peculiar to the action of the bacillus and prepares the way for the production of butyric acid by the bacillus. When this bacil-

lus begins action on milk it first coagulates the casein which is liquefied and softened by the enzyme and the bacillus is then able to proceed on the softened casein, converting it into lower compounds such as leucine, tyrosine and ammonia, which compounds are found also in the ripening process of cheese. There is another bacillus called subtilis, which forms an enzyme when acting on the casein of milk, coagulates and liquefies it, forming leucine, tyrosine, carbonic acid gas, ammonia and other putrefactive products, and the bacillus takes up the action on these compounds and reduces them to still lower compounds.

Nearly all putrefactive organisms have this power of producing enzymes, and this fact led many observers in the past to view the process of fermentation and putrefaction as merely chemical actions and in no way attributable to cell life.

In the putrid fermentation, one of the most common forms of bacteria found is the butyric ferment, where butyric acid is formed and other organisms produce fatty acids, converting starch, lactic acid, glucose and albuminous substances, and also fruit juices into fatty acids, carbonic acid gas. Lactic acid is fermented and converted into butyric acid with carbonic acid gas and hydrogen.

One of the most important processes of fermentation is that in which lactic acid is formed by the bacillus acidi lactici where the sugar of the milk is split up into lactic acid without the production of carbonic acid gas, and so far as we have studied the subject, this is the only fermentation which takes place where no gas is formed. Owing to the resisting power of this germ against high temperature, it is a very dangerous enemy in canning where milk is used in any product. This organism, which is not motile, produces wonderful changes in the milk after all other organisms have been killed off by the ordinary sterilizing process, when it is left in a pure cultivation to act on the milk sugar. This sugar is split up into lactic acid, and no sign is visible to disclose its action. The formula is simple, one molecule of milk sugar $C_6H_{12}O_6$ is split into two molecules of lactic acid $2C_3H_6O_3$, dividing the atoms into equal numbers, and no discovery of this change can be noticed until the can is opened. Under no circumstances can the trouble be ascertained except by opening the cans. Gradual heating will not induce any gases to form and swell the cans, because the action is completed. I regard this form of fermentation as one of the most peculiar processes ever discovered, and one which is all-important to the canner who uses milk in any product which he prepares.

If, however, there should be any butyric ferments present, they

would set up a fermentation of the lactic acid and convert it into butyric acid, carbonic acid gas and hydrogen, and the swelling of the cans will result from the formation of the gases so formed. The chemical formula will show this

$$\underset{\text{lactic acid}}{2C_3H_6O_3} = \underset{\text{butyric acid}}{C_4H_8O_2} + \underset{\substack{\text{carbon}\\\text{dioxide}}}{2CO_2} + \underset{\text{hydrogen}}{2H_2}.$$

These formulae will give an idea of the chemical action which takes place through the agency of these minute forms of bacterial life, which are present everywhere in the atmosphere in the seed form or spores. As we have observed before in all known cases, excepting that of the peculiar lactic fermentation, the decomposing processes are performed by hydration, which is the formation of gases, such as carbon dioxide, hydrogen, sulphuretted hydrogen and nitrogen. Generally the aerobic bacteria, by their requirements of free oxygen, cause the oxidation of the products of decomposition where nascent hydrogen combines with oxygen forming water H_2O.

The anaerobic forms deprived of free oxygen are dependent upon oxygen in combination for their oxidation of lower forms of decomposing elements. Their products are different from the aerobic forms, which is demonstrated by the fact that the gases set free contain less oxygen, because the oxygen which they obtain from the decomposing matter go to form their products, such as leucine, tyrosine, volatile fatty acids, ammonia, etc.

From the study of the statements made with reference to fermentation in previous pages, we draw conclusions thus, that the process of reducing a fermentable substance to elementary forms is not that of any single form of bacterium, but is the result of continual fermentation, beginning with the higher bacterial forms, which produce products which are then seized upon by lower forms which form more simple products, which in their turn are attacked by still lower forms until action entirely ceases or until such simple products are set free as elements which go to nourish the higher forms of animal and vegetable life.

It is interesting to note the influence of fermentation on plant life. The fermentation of dead organic matter, which covers the ground to a greater or less extent, is carried on by the aerobic bacterial forms, and oxidation takes place, which reduces the matter to lower forms, and the surface of the earth, being porous, the decomposition is carried downwards along with the spores of the

anaerobic bacteria, which begin at once to act on this matter, and being deprived of free oxygen, they break up the molecular structure of the matter to obtain whatever oxygen they need for their development, and products thus formed are no longer fit for bacterial action, but are just the necessary product for the nutrition of higher plant life. This fermentation is, of course, going on in a greater degree where the fermentable organic matter is found in large quantities. On manured ground, in the gardens and on the farms, this process is going on, and the action of micro-organisms is very necessary for the growth of the plants. If it were not for this process of fermentation and oxidation, plant life would be deprived of the elements of nutrition so necessary for their growth. This is the reason then that it is necessary for the farmer to place organic matter on his ground, not to give it any particular color, but to furnish food for the bacterial forms which set up the fermentation so necessary to produce the elements of nutrition for his growing crop. Any ground which is cultivated and the products carried away without replacing with some kind of fertilizer, soon becomes barren. The farmer frequently sows his ground in clover or grass and then plows it under and the fermentation of this cultivation soon takes place, and the ground is thus prepared for a cultivation of his salable crops. Sometimes there is an excess of fermentation which is brought about by fertilizing with a fermentable substance which produces too much heat for the proper growth of vegetation. This is the case where fresh manure of certain kinds is used; the fermentation is entirely too violent and the amount of heat generated by the oxidation is too great for the plant, and it often falls a victim to the bacterial life itself.

Manures and fertilizers which have undergone their first oxidation before spreading always bring the best results. There is a certain amount of heat set free by the final processes of its decomposition, but not enough to endanger the plant. This moderate supply of heat is very beneficial to the seed, which will soon sprout under its influence.

We must not, however, overlook some of the dangers which result from the manuring of ground, especially where the excreta comes from sources of infectious disease. Manure from stables is not dangerous, generally speaking, except that the growing plants will take up a great deal more nitrogenous matter from such soil. We often see corn come into the canning houses with beautifully formed and full ears, and the grains are large and full of milk; and that very corn sometimes causes the canner a great deal of trouble,

because the ears are covered with bacterial forms which have been decomposing the manures in the field, and have been dried up by the sun and wafted by the winds until they found a lodgment on the product, only waiting for the right time to come for the proper conditions to begin their work of destruction. Some of these bacterial forms are associated with the class of putrefactive ferments which are spore-bearing, and very high temperatures are required to kill them in the sterilizing processes.

The excreta of diseased animals are very dangerous fertilizers, and there are instances of infectious diseases transmitted in this way. Especially is this true where small garden truck is raised, which is eaten in its green state, the bacterial forms, disease germs, which are flourishing in these excreta, find their way to the leaves and edible portions, and when eaten sometimes cause infectious diseases.

It is the custom in China to save all human excreta, and it is also true in some localities in this country, where it is hauled out of the cities and dumped on neighboring farms. In China during the ravages of cholera epidemics, scientists made microscopical examinations of garden truck sold in the market places, and found on lettuce, kale and radishes the germs of cholera, which come from the excreta of people who were suffering with cholera. All these facts as stated have a bearing directly on the canning and preserving industries, and summing up what we have learned, we would suggest that the canner recommend to his growers special kinds of fertilizer, which would be free to a greater or less extent from the spores of putrefactive ferments, as they are so hard to kill in the sterilizing process. Of course the danger from ptomaines, where certain kinds of excreta are used, is possible where the product is of an albuminous nature, but we should say that, generally speaking, ptomaine poisoning from this source is not so common in canned vegetables as it is in the canning of meats and fish. We must not overlook the fact, however, that these dangers are possible, especially where the poisonous acid formed from tetanus, which is so common in manure, may find its way into the canning product.

We cannot fitly close this subject of fermentation, especially that which takes place upon and within the spongy surface of the ground, without calling atention to the effect of all this upon water. Since such large quantities of water are used in these industries, it is evident to the mind of any one, after studying the nature of fermentation and the organisms which cause it, that the water used should

be as pure and free from bacterial life as possible. Many canning houses get their supply of water from wells by pumping it up to tanks, from which it is used to make the various sauces, brines and syrups which go to fill up the can. When great quantities of organic matter are decomposing on the surface of the ground, bacteria are carried down into the soil and frequently find their way into wells and cisterns. This water is termed surface water, and should not be used where it comes from only a depth of 15 or 20 feet. Water is a great medium for bacteria, and they are found in great numbers in surface wells where there is seepage, carrying with it decomposing organic matter. We find in deep wells very few or no bacteria, and we would recommend the use of water only from such wells. If, however, this is found to be impossible and only shallow wells are available, the surface of the ground should be kept as clean as possible and as far away from any decomposing matter as is practical. There is a tendency on the part of canners to dump their cobs, when packing corn, and their waste of every character in the immediate vicinity of the factory. This should be avoided, not only for fear of contaminating the water, but to prevent the air from being laden with unusual numbers of ferments.

Fermentation, then, as we have studied it in these pages, is a chemical process, in one form accomplished by the yeast plant, which converts substances of a nitrogenous nature which contain sugar, into alcohol, carbonic acid gas, glycerine, succinic acid and other fatty acids, attended with heat, and accomplished by breaking up the molecules of sugar to obtain the oxygen necessary for their reproduction or their propagation, when the supply of oxygen is cut off; that is, the free oxygen of the atmosphere. In the presence of free oxygen the yeast plant will develop more rapidly, but acts less as a ferment, because it obtains whatever oxygen it needs for its development from the atmosphere. But when the supply of oxygen is cut off, the molecular construction of the sugar is torn apart and the oxygen is employed to make the chemical change. We have seen that the pencillium and all other mold fungi, which grow naturally on the surface of moist acid substances, have the same characteristics as the yeast plant when submerged or imbedded in a fermentable substance, which cuts off the supply of oxygen necessary for their natural development. Under these conditions they resemble the yeast plant very closely, both in appearance and character. The process of fermentation is carried on after the products are formed by the higher class of bacteria, and their products are attacked and decomposed until elementary forms are

obtained, when they cease to exist. So we have fermentation in which alcohol is formed; acidity, in which acids are formed from alcohol, and putrefaction, in which acids are broken up into more simple acids or fatty acids, which may be volatile. A molecule resolved into simple forms is the great scheme of nature for reducing accumulations of the past into nutriment for the future. Thus animal and vegetable life is laid low and the elements go to nourish new life.

CHAPTER VII.

DIRECTIONS FOR STUDYING BACTERIA. METHODS TO OBTAIN PURE CULTURES. APPARATUS TO FACILITATE THE STUDY. INNOCULATION OF SOLID CULTURE MEDIA. HOW TO CULTIVATE ANAEROBIC ORGANISMS. HANGING-DROP CULTURES. STAINING.

A great many of these bacteria are useful, others are causes of disease in man and animals and still others attack our food and make it unfit for consumption. Bacteria, by which we mean the whole catalogue of monads or germs, are developed either from spores or dried-up forms, and the development is marked by an increase of protoplasm. As with the higher forms of the vegetable kingdom, which spring from seeds, so these spores and dried-up forms are nothing more than the seeds. These seeds are held in the atmosphere in the dust or clinging to any floating material. So infinitely small are they that the microscope fails often to reveal them, and we know them only after they have developed, when they may be viewed and studied under microscopic power. A few of the following pages will be given to the more recent methods of studying bacterial life.

A steam sterilizer is necessary, with which we can sterilize our culture media. The ordinary process kettle or steam retort is good, because any temperature needed can be obtained.

An incubator is necessary, and any of the arrangements for artificial egg hatching are all right. With the regulated temperatures we can cultivate our bacteria.

Test-tubes, flasks, cotton wool, pipettes and various laboratory paraphernalia are all useful.

A microscope with various magnifying appliances, an oil immersion lens of 1000 diameters and all the latest accessories to a good instrument. Various germicides should also be on hand for sterilizing tubes, flasks, etc.; also a burner to sterilize needles and instruments by passing them through the flame.

FLUID CULTURE MEDIA.

Bouillon.—Cut up the beef in small strips, and put them into an open kettle, covering same with pure cold water. Bring this to a very gentle simmer and keep it so for six or eight hours, adding water to replace evaporated juice. When the fluid has extracted all the juice, draw off from the bottom, leaving the fat in the kettle. The bouillon may be clarified with egg albumen or blood. After the bouillon is clarified it may be rendered slightly alkaline by adding a saturated solution of mixed sodium hydrate, sodium carbonate or sodium phosphate. The bouillon is now sterilized by boiling same in flasks, test-tubes or cans, discontinuously; that is, boiling for twenty minutes for three successive days, allowing same to stand in a cool place between heatings, but the flasks and tubes must be plugged tightly with cotton wool. If sealed hermetically in a tin can, it may be sterilized by giving it one hour at 250° F. in the steam retort. The bouillon may be made suitable for the propagation of various organisms by the addition of various substances, such as glycerine, salt, albumen peptone, cane or grape sugar, acetic acid, mannite, etc. Liebig's extract of beef, diluted in water, is also an excellent culture medium, and must be sterilized when put up in flasks, stoppered with cotton wool, by Tyndall's discontinuous process, by which all organisms may be killed at low temperatures. After standing in a cool place for eight or ten hours the second heating will kill the germs which have developed from some of the spores. More spores developing in the next period are killed in like manner and probably all will succumb in another heating. Infusions may also be made from fruits, vegetables, beer wort, etc. Beer wort and prune juice is an excellent medium for the growth of mold fungi and mucors, and also yeasts. These should be sterilized by either Tyndall's discontinuous method or by sealing in cans and given high temperatures in a retort, but this is not always as reliable as Tyndall's method.

MILK.

Milk is a very favorable culture medium, and is easily obtained, but great care is necessary to make it perfectly sterile, because it is so easily scorched when given high temperatures, and in the discontinuous process it often requires an hour's boiling at each time for three days.

SOLID CULTURE MEDIA. POTATO CULTURE MEDIUM.

Cut the potato in strips and steam. After cooling with a sterilized apple corer, cut out cylinders and cut off each end, and insert

the cylinder into a test tube where a small quantity of cotton wool is inserted into the bottom and sterilized by dry heat. A small quantity of distilled water is then let into the tube to moisten the cotton wool and the potato will rest on this and the tube will be closed at the top with a plug of cotton wool. After this tube is boiled for a couple of hours the potato is ready for culture of bacteria.

Another way.—The potato may be pared and steamed, cut into small pieces and filled into a tin can, which is then sealed. Boil this for twenty minutes, then tap and resolder. Boil this again for one hour.

BREAD CRUMBS.

Evaporate the moisture from several slices of bread by spreading them in an oven of a temperature of 200° F. Reduce the slices to small crumbs and cover the bottom on the inside of the flasks. Moisten the crumbs with distilled water, and after they are thoroughly moist, sterilize same, after plugging mouths of the flasks with cotton wool, by discontinuous heating for three days. By adding various fruit juices and acids this makes a very favorable medium for mold fungi, mucors and other ingredients.

EGG ALBUMEN.

Eggs are also used for cultures of micro-organisms. After washing the shell in a solution of bichloride of mercury, a small chip is carefully removed and a culture of a specified organism is inserted through the skin, which is then closed and sealed with a sterilized plaster. The culture will develop and its action studied after the development.

KOCH'S GELATINIZED MEAT PEPTONE MEDIUM.

To prepare Koch's meat jelly, or solid gelatine medium, cover a small piece of lean beef with water and add a drop or two of muriatic acid; allow this to stand in a cool place for one day, after which squeeze through a cloth. To this fluid add 10 grams of albumen peptone, 5 grams common salt, and 100 grams of pure gelatine. Mix in a flask and boil for half an hour until the gelatine is thoroughly dissolved. Render this liquid slightly alkaline with common soda and boil again for an hour; after this is filtered it is a very proper medium for the propagation of pure cultures of bacteria.

AGAR PEPTONE MEAT JELLY.

In place of the gelatine in the above, we may use 1.5 per cent. agar. This is prepared in the same manner as the gelatine jelly, except that it requires a more prolonged boiling before it can be properly filtered. It is made as follows: Cut into small pieces 15 grams of agar, place in a porcelain basin and soak in strong brine for one day; remove the particles of dirt and wash thoroughly, after which drain off the water. To the 15 grams of agar add 1000 grams of water, one pound of beef, 10 grams of peptone, 5 grams of salt, or 1000 grams of water, 5 grams Liebig's extract of beef, 30 grams of peptone and 5 grams salt. In the first formula the beef is first extracted; the preparation after this is the same in both cases. Before transferring fluid gelatine or agar meat broth or other fluid media to test tubes or flasks, these should be perfectly sterilized. With a sterilized pipette the fluid is run into these vessels, the plug is returned and the vessels are then sterilized for ten minutes or a quarter of an hour discontinuously for three successive days. Sterilized paper is then fastened over the mouth.

TO INNOCULATE SOLID CULTURE MEDIA.

Hold the test tube inverted in the left hand, the cotton wool is twisted in the mouth to break the adhesion, and if there is any dust on the cotton wool it must be first singed. The plug is then removed, great care being taken that it comes not in contact with any source of infection. The platinum or glass needle with its charge of seed material (by this I mean any form of bacteria desired to be cultivated) is then plunged straight into the gelatinous mass; then carefully withdraw and replace the plug.

TO CULTIVATE ANAEROBIC ORGANISMS.

A simple method of cultivating anaerobic bacteria is that described by Fraengel, who uses a test tube with a long and a short glass tube passing through an india rubber cork. This, after being carefully sterilized, has about a cubic inch of nutrient gelatine poured into it. The inoculation is made and the india rubber cork with its two tubes is pushed home into the mouth of the test tube, after sterilizing is sealed. A stream of hydrogen is passed through the liquefied gelatine for four or five minutes and the tube sealed in a flame. Another very good method is to boil a quantity of agar in a test tube, then cool as quickly as possible in cold water.

It is then inoculated with anaerobic organisms, a layer of melted gelatine is poured over the surface, and when this is cool a drop of bacillus subtilis is run on the surface from a pipette. As the bacillus subtilis develops and grows, it uses up the oxygen at the surface and the organism below is thus placed in an anaerobic condition. Molds have the same characteristic, as the subtilis is using up all the oxygen at the surface. Anaerobic bacteria and aerobic bacteria made to grow without oxygen can be cultivated in hermetically sealed tin cans. This is a far simpler method of cultivating these torms and one which any canner can easily follow himself without any lessons in fine laboratory work.

HANGING DROP CULTURE.

A glass slide such as is commonly used under the microscope is obtained, where a little hollow place has been ground out and polished, so that a cover glass laid over this hollow place will enclose quite a little air chamber. If a tiny drop of some inoculated fluid be hung on the under side of the cover glass within this air chamber, and the cover glass is then sealed fast to the slide, a flat surface of the hanging drop will be exposed to the magnifying lens of the microscope. Here the bacteria may be watched and studied as they develop, and this is one of the most beautiful methods of examining their character. Micro-photographs can be obtained, and those we have reproduced in this work were made from this hanging-drop culture.

STAINING BACTERIA.

On account of the transparent nature of a very great number of bacteria, it is necessary to resort to dyes, in order to be able to see them. Certain forms of bacteria look very much alike but are susceptable to certain kinds of dyes, which enables the observer to distinguish them.

METHYLENE BLUE.

This color is kept as a saturated solution of alcohol. Diluted in water it gives a fine blue color in cover glass views. After drying the object and passing over the flame of a lamp, it is saturated with a diluted methylene color for a few minutes, then washed in water and turned on edge to allow the water to flow off. It becomes dry again and is mounted in xylol balsam. Kuhne's methylene blue is made as follows, and is a good stain for bacteriological work: Three grams of methyl blue, dissolved in 20 cubic centimeters alcohol

and 200 cc. of a 1-to-20 watery solution of carbolic acid. Specimens left in this solution will not take on too much stain. After washing in pure water and afterward with a weak muriatic acid water the specimens will assume a pale blue. They are then mounted and the bacteria will be plainly seen. Fuchsin is also used, which brings out the organisms plainly to view. Other dyes are also used, viz: iodine, aniline, eosine, victoria blue, etc., etc.

There are works written especially on staining, and any one desiring to take up the subject fully, should read Kuhne's work.

PURE CULTURES.

For a long time bacteria were claimed for the animal and vegetable kingdoms, but after pure cultures were obtained and their manner of propagation became known, they were classed as belong-to the vegetable kingdom, because they multiply by fission, and we find the peculiarities of the vegetable kingdom are characteristic of bacteria, viz: the sending out of buds, branching and lengthening, etc.

On account of the poor appliances and the minuteness of the organisms, together with the fact that they were seldom if ever found growing alone, the question of obtaining pure cultures became a very perplexing problem. Pasteur obtained almost pure cultures by separation, by feeding to the kind of organism he wished to study a food on which it particularly thrived and which the other other organisms failed to use for a propagating medium. He was thus able to get practically pure cultivations, although at times he failed to exclude some different kinds which had affinity for the product he was using as a medium, but their growth did not hinder him from obtaining the results he was after.

Klebs adopted a fractional method to obtain pure cultures. He took a lively growth and transferred it to new media, and by adding different kinds of juices to these media for which his cultures had special affinity, he succeeded in obtaining practically pure cultures. He could only obtain the common forms by this method, however, and even they could not be relied upon as being absolutely pure.

Roberts and Cohn obtained pure cultures of various bacilli by boiling a fermenting fluid so as to kill all forms excepting the more resistant. They obtained by this method quite pure cultures of various spore-bearing bacilli, among which was the bacillus subtilis. This method, however, had a very limited application.

Lister obtained fairly pure cultivations by distribution. He

took a certain growth and distributed it into large quantities of fluid, until a drop would contain not more than a single organism. By placing a single drop of fluid in a large number of tubes containing sterilized media, he was enabled to get very good cultivations. This method was very laborious and complicated, however, especially when working with organisms which were difficult to grow, such as the anaerobic forms.

It is to Koch, Klebs and Brefeld that we owe the knowledge of obtaining pure cultures easily. Koch took the gelatine method and isolated the organisms so that the colonies formed could be transplanted to other media and there studied in their purity. After this simple method was discovered, the study of this science was taken up with renewed energy, and subjects of fermentation and putrefaction were studied more carefully and definite knowledge was obtained which began to clear up many mysteries.

CHAPTER VIII.

A SUMMARY OF THE CHARACTERISTICS OF VARIOUS ORGANISMS FOUND IN FOOD PRODUCTS. BACILLUS LACTICI ACIDI. BACILLUS BUTYRICUS. BACILLUS AMYLOBACTER. BACILLUS PRODIGIOSUS. BACILLUS VISCOSUS. BACILLUS FLUORESCENS PUTIDUS.

BACILLUS ERYTHROSPORUS. BACILLUS CYANOGENUS. BACILLUS SUBTILIS. SACCHAROMYCEL APICULATUS. SACCHAROMYCES ELLIPSORDEUS. SACCHAROMYES CEREVISIAE. COMMA BACILLUS. KLEBS-LOEFFLER BACILLUS. TYPHOID BACILLUS. TETANUS BACILLUS. BACILLUS LACTICI ACIDI.

DESCRIPTION. Occurs in short, stout rods, 1 to 1.7 μ* in length and .3 to .4 μ in thickness; usually arranged in

*1 $\mu = \frac{1}{25000}$ of an inch.

pairs, sometimes, though not often, in chains of four; well-marked refractile bodies, which are regarded as spores, which are usually placed at the ends of the rods.

MOTILITY. No motion.

TEMPERATURE. From 10° C. to 45° C. it can develop.

CHARACTER. Aerobic, but can be made to grow anaerobic.

GELATINE. It grows on gelatine plates as small, white points, which gradually become opaque and moist-looking, forming a thick layer of from one to two millimeters in diameter. Under the microscope these colonies appear to be dark yellow in the middle. The margins are irregularly indented and toothed.

IN TUBES. In tubes its growth appears as small granules along the line of puncture; surface growth thick, moist and opaque; grows very slowly. This bacillus was found by Hueppe in sour milk.

BACILLUS BUTYRICUS

DESCRIPTION. Occurs in large, thick rods, with rounded ends of from 3 to 10 μ in length and 1 μ in breadth; often forms chains. This bacillus gives rise to large, well-defined spores, which are very resistant to heat.

MOTILITY. The bacillus is very motile.

TEMPERATURE. Grows very rapidly at a temperature of from 35° to 40° C.

CHARACTER. This is a strongly anaerobic organism.

GELATINE. Grows on plates in the deep layers of gelatine as a delicate yellow mass, which assumes a brown granular appearance later; gelatine is rapidly liquefied and runs together.

AGAR. On agar the bacilli grow as viscid, superficial yellow layers.

GELATINE TUBES. In gelatine tube punctures, cultures rapidly cause liquefaction along the tracks of the needle, the fluid becoming cloudy. The superficial is grayish white or yellow, forming a delicate fetid mass.

FERMENTATIVE CHARACTER. This is one of the forms of bacilli giving rise to butyric fermentation, and is found in milk and putrefying vegetable and animal matter. Its sheath splits lengthwise for the escape of the spores.

CLOSTRIDIUM BUTYRICUM OR BACILLUS AMYLOBACTER.

The character of this organism is very similar to the one described above, but gives off a large quantity of gas which has the odor of butyric acid, when growing on a solid nutrient medium.

DESCRIPTION OF FUNCTIONS. It is strongly anaerobic and transforms sugar, starch, dextrine and the lactates into butyric acid, setting free carbonic acid gas (CO_2) and hydrogen.

Gelatine is liquefied and a regular fetid scum forms on the surface.

TEMPERATURE. Grows rapidly at 35° to 40° C.

BACILLUS PRODIGIOSUS.

DESCRIPTION. This organism occurs as egg-shaped cells about 1 μ in diameter; sometimes it is rod-shaped, or may occur in the form of threads. Multiplies by division with marvelous rapidity. One of the smallest forms seen. One cubic inch could contain 1,000,000,000,000,000 (one quadrillion).

MOTILITY. It is non-motile as a rule; under certain conditions has a peculiar motion.

TEMPERATURE. Grows rapidly at 20° to 22° C.

CHARACTER. Aerobic—facultative anaerobic.

GELATINE. On plates it grows in the deep layers as gray points; the superficial growths form small gray round colonies about one millimeter in diameter; these sink into the gelatine, which is rapidly liquefied, but remains clear. Viewed with ordinary low powers in the microscope, the deep colonies are seen to be rounded or oval and have sharp outlines. When the gelatine is liquefied a beautiful red color makes its appearance.

AGAR. On agar, in the deep layers it grows as gray points. On the surface, where there is free oxygen from the air for the growing cultivation, a beautiful red color appears.

POTATO. A beautiful red layer is formed, which is moist.

BREAD. Form a beautiful red patch, which has given the organism the name of bleeding bread, because the spot so much resembles blood.

ONION. On the surface of chopped onions a beautiful pink color is given. The bacilli themselves are colorless, but form this red pigment at lower temperatures. It has the odor of herring brine so characteristic of putrefying substances. At higher temperatures it loses both these characteristics.

MILK. On placing a culture in sterilized milk, the milk is curdled and casein is precipitated.

This organism has the power of turning milk sugar and saccharose into lactic acid and carbonic acid gas. It is a very common form and occurs in almost all spontaneous fermentation and putrefaction. It is also very resistant to high temperatures.

BACILLUS VISCOSUS.

DESCRIPTION. Occurs in pairs of small cocci forming chains and zoögloea, surrounded by an envelope of slimy or mucilaginous matter. The cocci measure 1.2 to 1.5 μ in diameter.

Under certain conditions they assume rod forms from 2 to 3 μ in length and 1 μ in breadth. Multiply by division.

MOTILITY. They are not motile.

TEMPERATURE. At 20° to 35° C. they grow rapidly.

CHARACTER. Aerobic, faculative, anaerobic.

GELATINE. On plates forms gray spots, which appear cloudy and moist. Gelatine is liquefied and gummy.

POTATO. They grow in a colorless, moist patch over the whole surface. No envelope is visible when exposed freely to the atmosphere.

BACILLUS FLUORESCENS PUTIDUS.

DESCRIPTION. Short, thin bacillus, with rounded ends, similar to the bacillus prodigiosus. Green pigment bacillus. Multiplies by division.

MOTILITY. It is a very motile organism.

TEMPERATURE. 20° to 35° C.

CHARACTER. Aerobic, faculative, anaerobic.

GELATINE. In the deep layers of gelatine plates forms dark colonies. On surface appears round with irregular outline, giving the surrounding gelatine a greenish fluorescent appearance.

IN TUBES. In tubes there is cloudiness along the track of the needle and gelatine is colored green.

POTATO. Grows rapidly on potato, forming brown and gray colored layers.

MILK. Gives milk the green color so often seen.

MEAT. Forms green color around the fatty portions and bone, gradually covering the whole surface.

ODOR. The odor is strongly like herring brine or fish, and very offensive.

It is resistant to high temperatures, and is a common organism found in nearly all putrefying matter.

BACILLUS ERYTHROSPORUS.

DESCRIPTION. Occurs as slender with rounded ends, single or in threads, which contain numbers of dull red-colored spores, which may be distinctly seen.

GELATINE. On plates forms whitish colonies which spread over the whole surface, giving the gelatine a fluorescent appearance. The center of the colonies are opaque and brownish, the outer edges are yellowish green, not so opaque, and a radiate marking is seen.

IN TUBES. Along the track of the needle and at the surface the growths are rapid, and the gelatine is colored a yellowish green.

POTATO. On potato forms reddish brown patches.

This is an organism found commonly in putrefying matter of albuminous character and in water.

BACILLUS CYANOGENUS. (BLUE MILK BACILLUS.)

DESCRIPTION. Occurs in club-shaped rods from 1 to 4 μ in length by .3 to .5 μ in breadth. Sometimes when spores form in the middle it has a lemon shape. Spores oftener form at the ends, giving club shape to it.

MOTILITY. It is an exceedingly motile organism.

TEMPERATURE. At 15° to 18° C. develops color rapidly. At 37° C. no color is formed at all.

GELATINE. On plates forms rounded, whitish, finely granular colonies with smooth outlines, while the surrounding gelatine takes on a light green or greenish brown color.

IN TUBES. In gelatine along the track of the needle it develops with a club-shape or drumstick appearance, with a white spore-bearing end or head. The surrounding gelatine becomes a greenish blue, or sometimes very dark color.

AGAR. On agar it presents much the same appearance, but sometimes the growth appears gray in color. The green color is not so marked as in a gelatine medium.

POTATO. It forms a yellowish layer near the point of inoculation, while the surrounding potato is colored green.

BLOOD SERUM. No color is imparted.

MILK. When alkaline, forms a slate color. When slightly acid, imparts a blue color.

This is a very common putrefactive organism, and occurs in milk more frequently than anywhere else. It can withstand the boiling temperature for hours, and is a very difficult organism to kill in spore form.

BACILLUS SUBTILIS.

DESCRIPTION. Occurs in stout rods from 4 to 6 μ in length by 2 μ in breadth, having slightly rounded ends. Bears large, well-defined spores measuring 1.2 μ in length by 6 μ in breadth when the supply of nutrition is gradually cut off. Multiplies by sending the spore from a break in the cell wall across the middle.

GELATINE. Grows on plate cultures as white, rounded colonies with radiations; gelatine is rapidly liquefied.

IN TUBES. Along the track of the needle liquefies the gelatine, beginning at the surface; occurs first as small white colonies, which have a yellowish brown color with hair-like margin; outside this is a narrow clear zone, and beyond this is a grayish radiating layer. This may be seen with a low power.

AGAR. Forms a dry, wrinkled, white layer of creamy appearance.

POTATO. Grows on potato in moist white or creamy layers, which afterwards become dry and granular.

SERUM. Liquefies blood serum.

MOTILITY. Is a very motile organism, multiplying rapidly.

TEMPERATURE. Grows best at 30° C.

CHARACTER. Strongly aerobic, faculative, anaerobic.

The bacilli commonly occur in infusions of hay which has been boiled. The spores are very resistant to heat, in fact, they are the most resistant forms to high temperatures that we have met.

SACCHAROMYCES APICULATUS.

DESCRIPTION. Occurs in cultivation fluids of fruit juices as lemon-shaped cells. Cells sometimes elongated, crescent and rod-shaped. Multiplies by sending out two kinds of buds, one oval and the other lemon-shaped. No spore formation observed.

IN WINE. Sets up a bottom fermentation, which is characteristic on all juices suitable to its development, producing alcohol feebly.

ON CANE SUGAR. Does not invert.

ON DEXTROSE. Ferments dextrose feebly, not completely.

It is a spontaneous ferment deposited from the air in fruit juices. Found during season on the fruits. In winter is found in the soil under the trees.

SACCHAROMYCES ELLIPSOIDEUS.

DESCRIPTION. Occurs as cells usually rounded or ellipsoidal-shaped, sometimes in sausage form. Bears spores with two to four in a single ascus, which measure from 2 to 4 μ in diameter. Spores develop rapidly at 25° C. Egg-shaped spores.

ON BEER WORT GELATINE. Colonies on surface

form network along the line of the inoculation streak. The surface membrane forms rapidly in eight to twelve days at 33° to 34° C.

IN BEER WORT. Grows as a low ferment. Produces alcohol.

ON TOMATO. Multiplies rapidly, producing cloudiness.

ON FRUIT JUICES. Produces alcohol. Fermentation and film-formation is rapid. Multiplies by budding.

SACCHAROMYCES CEREVISIAE.

DESCRIPTION. Cells are rounded or slightly ellipsoidal, which give off small cells or buds. Forms in a film in threads which grow long and regular. The yeast cells form nuclei. Forms spores well defined from 2.5 to 6 μ in diameter, which are highly refractile and easily seen.

TEMPERATURE. Films form in seven to ten days at 20° to 22° C. Form sausage-shaped cells at 6° to 15° C.

ON TOMATO JUICE. Spontaneous fermentation, producing alcohol and a film in five days.

ON FRUIT JUICES. Fermentation rapid. Multiplication of cells very fast. Film forms in eight days. Produces alcohol, gives off carbonic acid gas. This is a typical English high yeast.

COMMA BACILLUS. (CHOLERA.

DESCRIPTION. It belongs to the spirilla; usually occurs as slightly curved rods measuring from 1 to 2 μ in length and from .5 to .6 μ in thickness. Instead of rods may be grouped in pairs; forms O's, or may be reversed, forming shapes like S; sometimes forms wavy threads of 10 to 30 bends.

MOTILITY. It is a very motile organism.

TEMPERATURE. Thrives best at blood-heat, or even higher.

PLATE CULTURE. At 20° C. to 30° C. forms light yellow colonies, having irregular outlines. Liquefies gelatine slightly and sinks to the bottom, leaving a clear space.

POTATO. Grows on potato as a brownish film.

PUNCTURE GROWTH IN GELATINE. Growth takes place along the whole track of the needle, first as a delicate white cloud, and after the gelatine is liquefied leaves a clear zone around the streak. The surface gelatine is liquefied more rapidly than deeper down.

ON AGAR. On surface grow as pale, translucent streaks, and below the streak a slight opalescence occurs, which is characteristic. Agar is not liquefied.

MEAT BROTH. Rapid growth, forming grayish pellicle on surface.

BLOOD SERUM. Rapid growth. Slight liquefaction.

MILK. Milk is an excellent nutrient medium for the organism, which grows rapidly, giving an aromatic, sweetish odor. Do not thrive in the presence of acids which are germicidal to them. The organism produces ptomaine poison. Acting on albuminous substances producing poisonous alkaloids.

KLEB'S-LOEFFLER BACILLUS (DIPTHERIA.)

DESCRIPTION. Occurs in varying length rods, straight or slightly bent, 3 to 6 μ, with one or both ends slightly swollen.

MOTILITY. It is a very motile organism.

CHARACTER. Aerobic, faculative, anaerobic.

TEMPERATURE. Grows rapidly at blood heat. Can live at 98° C.

GELATINE. Does not grow on meat peptone gelatine.

BLOOD SERUM SOLIDIFIED. Grows in pure cultures.

AGAR. Grows at 35° C. but soon overrun by putrefactive organisms. On blood serum it forms colonies visible to the naked eye in one day, and it is the only organism known to do that.

Colonies grow as small rounded grayish points, the center of which are more opaque than the periphery. They spread rapidly, form grayish rounded discs, and develop long before any colonies of other organisms are visible to the eye.

AGAR PLATES. Colonies are coarsely granular, dark brown, rounded or oval. Colonies run together, making irregular outlines.

Superficial colonies are lighter in color, less dense, with irregular border.

The Klebs-Loeffler bacillus forms ptomaines and toxines which are deadly poisons, resembling snake bite, and cause muscular tremors, convulsions and death. It is easily stained by Loeffler's alkaline methylene blue or by Gram's gentian violet method.

TYPHOID BACILLUS.

DESCRIPTION. Occurs in short, somewhat thick rods, about 2 to 3 μ in length and .3 to .5 μ in thickness. They are rounded at the ends. In pure cultivations grows in long threads, developing flagella. Multiplies by division.

MOTILITY. Wavy motions in rods and threads due to flagella, which give the organism a snake-like movement.

TEMPERATURE. Develops rapidly at blood-heat. Aerobic forms are resistant to heat.

CHARACTER. Either aerobic or anaerobic.

PLATE CULTIVATIONS. Develops in the deeper layers of the gelatine as small white points; on surface as moist gray colonies with irregular margins. There is no liquefaction around the growths.

IN TUBES. Develops rapidly along the track of the needle. Surface cultures resemble mother of pearl in appearance; grows over the entire surface, form a blue-gray film, also same color along the track of the needle; outside this is milky in appearance.

POTATO. Grows on surface; invisible except by moist appearance. Thrives exceptionally well where the nutrient is slightly acid.

PRODUCTS. Forms an acid excretory product, which is different from other forms which produce alkaloids. This acid has been named typhotoxicon, and is a poisonous product, classed among the ptomaines.

RESISTANT POWER. It is killed at 100° C. in ten minutes; 14° C. is too cold for it and often kills it. Sunlight and X-rays kill the organism.

TETANUS BACILLUS.

DESCRIPTION. Bacillus is drumstick-shaped. Occurs sometimes a long thread, which breaks up; also in shorter rods, which develop large, well-defined spores at the ends.

MOTILITY. The rods are motile.

TEMPERATURE. Spores develop at blood-heat in thirty hours.

CHARACTER. Anaerobic.

PURE CULTURES. Very hard to obtain on account of anaerobic character. Is cultivated in an atmosphere of hydrogen. After sowing the seed in gelatine in the hydrogen atmosphere, it developed rapidly along with other drumstick-shaped organisms

and give rise to spores. By heating them to 80° C. all other forms were killed, also the tetanus bacilli, but the spores were not. These spores when transplanted again into another nutrient gelatine developed a pure cultivation.

PRODUCTS. From pure cultivations their products were seen to be a basic poison or ptomaine.

Tetanin, tetano-toxin or toxalbumen, both alkaloids, are obtained.

FOUND. Dry spores develop from the soil, also from the cleanings of stables. Found wherever there are horses.

NATURE OF POISON FORMED. The ptomaines formed by this organism produce convulsions, tremors, lockjaw and death. Sometimes gets into canned meats, fish, etc., where anaerobic conditions are favorable to its development.

CHAPTER IX.

SCIENTIFIC PRINCIPLES INVOLVED IN CANNING AND PRESERVING TEMPERATURES. VACUUM. ANAEROBIC BACTERIA AND THEIR ACTION. FORMS GROWING IN AN ANAEROBIC STATE. SPRING BOTTOMS IN CANNED GOODS. CAUSES. PRECAUTIONS. CLEANLINESS. DISPOSAL OF WASTE MATERIAL. SOLDERING SOLUTIONS.

Wherever it is possible it is better to sterilize any goods by using higher temperatures than boiling, which is 212° F., unless the discontinuous process is used, in which case no higher temperature is needed. The discontinuous process at the boiling temperature could not be used, however, if it was necessary to cook the product very much. Meats would not cook tender by that process, so the higher temperature would be better.

By using high temperatures, the time of cooking is shortened, and the sterilizing effect is more perfect. Many bacteria which might live through a boiling process would soon perish under a high temperature.

The following list of products and the necessary temperatures, together with the required time, will be valuable. It is understood that these products are either exhausted or hot before this process is begun:

Corn	250° F	55 minutes			
Young Peas	240° F	15 "			
Marrowfats	"	25 "			
Milk	250°	50 "			
Products Containing Milk	"	20 "	if liquid		
Meats	"	55 "			
Meat Soups	"	50 "			
Peaches	240°	no time			
Cherries	"	2 "			
Plums, etc.	"	2 "			
Pears	"	12 "			
Tomatoes	"	5 "	hot	cold pack	10 minutes.
Apples	"	2 "			
Berries	"	2 "			
Lima Beans	"	25 "			
Pineapple	"	8 "			
	"	[illegible] "			

ERRATA.

The time required in processing has been changed after going to press. It should read: Products containing milk 250° 50 minutes. Tomatoes 240° 10 minutes, Cold pack 15 minutes. In the 39th line it should read: or the temperature must be 250° for 50 minutes.

heat themselves of course require a longer time and a higher temperature. Fruits and tomatoes, while exposed to the air just as much as other products, do not furnish nutrition for many of the more resistant forms of bacteria, and their acid juices act in many instances as germicidal agents against them. The only very resistant forms inimical to fruits and tomatoes seem to be the molds, which perish at 212° F. in a moist heat. We cannot say positively that there are no living germs within a can simply because it does not swell. There may be many which do not perish at once by the sterilizing heat, but they do not develop because the substrata are not suitable propagating media for them, consequently they are dormant. In the case of milk and products such as soup which contain milk, however, a fermentation may take place without the cans swelling by the agency of the milk bacilli, which break up the sugar of milk into lactic acid without any other chemical changes and the chemical formula will be shown thus $C_6 H_{12} O_6 = 2C_3 H_6 O_3$, which is, one molecule of sugar equals two molecules of lactic acid.

In order to sterilize milk either the discontinuous process must be used or the ~~temperatures~~ temperature must be 250° F. for ~~40~~ 50 minutes.

VACUUM.

There has been and there is to-day a very erroneous belief that the perfect keeping qualities of goods depend upon a vacuum being formed. Some packers and preservers make a special point of trying to secure this vacuum to insure the keeping qualities of their goods, believing that if the supply of oxygen is cut off from any bac-

and give rise to spores. By heating them to 80° C. all other forms were killed, also the tetanus bacilli, but the spores were not. These spores when transplanted again into another nutrient gelatine developed a pure cultivation.

PRODUCTS. From pure cultivations their products were seen to be a basic poison or ptomaine.

Tetanin, tetano-toxin or toxalbumen, both alkaloids, are obtained.

FOUND. Dry spores develop from the soil, also from the cleanings of stables. Found wherever there are horses.

NATURE OF POISON FORMED. The ptomaines formed by this organism produce convulsions, tremors, lockjaw and death. Sometimes

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Wherever it is possible it is better to sterilize any goods by using higher temperatures than boiling, which is 212° F., unless the discontinuous process is used, in which case no higher temperature is needed. The discontinuous process at the boiling temperature could not be used, however, if it was necessary to cook the product very much. Meats would not cook tender by that process, so the higher temperature would be better.

By using high temperatures, the time of cooking is shortened, and the sterilizing effect is more perfect. Many bacteria which might live through a boiling process would soon perish under a high temperature.

The following list of products and the necessary temperatures, together with the required time, will be valuable. It is understood that these products are either exhausted or hot before this process is begun:

Corn	250° F	55	minutes	
Young Peas	240° F	15	"	
Marrowfats	"	25	"	
Milk	250°	50	"	
Products Containing Milk	"	20	"	if liquid
Meats	"	55	"	
Meat Soups	"	50	"	
Peaches	240°	no time		
Cherries	"	2	"	
Plums, etc.	"	2	"	
Pears	"	12	"	
Tomatoes	"	5	"	hot cold pack 10 minutes.
Apples	"	2	"	
Berries	"	2	"	
Lima Beans	"	25	"	
Pineapple	"	8	"	
Oysters, No. 1 cans	"	10 to 12	"	
Oysters, No. 2 cans	"	12 to 15	"	

The differences in temperature required for sterilizing the above are due to their nature. Products which are poor conductors of heat themselves of course require a longer time and a higher temperature. Fruits and tomatoes, while exposed to the air just as much as other products, do not furnish nutrition for many of the more resistant forms of bacteria, and their acid juices act in many instances as germicidal agents against them. The only very resistant forms inimical to fruits and tomatoes seem to be the molds, which perish at 212° F. in a moist heat. We cannot say positively that there are no living germs within a can simply because it does not swell. There may be many which do not perish at once by the sterilizing heat, but they do not develop because the substrata are not suitable propagating media for them, consequently they are dormant. In the case of milk and products such as soup which contain milk, however, a fermentation may take place without the cans swelling by the agency of the milk bacilli, which break up the sugar of milk into lactic acid without any other chemical changes and the chemical formula will be shown thus $C_6 H_{12} O_6 = 2C_3 H_6 O_3$, which is, one molecule of sugar equals two molecules of lactic acid.

In order to sterilize milk either the discontinuous process must be used or the temperatures must be 250° F. for 40 minutes.

VACUUM.

There has been and there is to-day a very erroneous belief that the perfect keeping qualities of goods depend upon a vacuum being formed. Some packers and preservers make a special point of trying to secure this vacuum to insure the keeping qualities of their goods, believing that if the supply of oxygen is cut off from any bac-

teria within the goods, that their power to cause fermentation is destroyed. For this reason many bottlers of condiments exhaust their bottles and use a very large cork, which they compress to keep out the germs, and prevent fermentation of those within.

The only benefit a vacuum is to a canner is its power to draw back the ends of the cans which are bulged out in the cooking process, for all other purposes it is a detriment instead of a help in preventing fermentation.

From our study of fermentation we learned that there were two kinds of micro-organisms with reference to life with or without oxygen. We learned that there were some organisms which could only live without free oxygen, and these we called anaerobic.

We learned that there were others which needed oxygen for their development and these we call aerobic. The most of the aerobic germs grow rapidly in the presence of free atmospheric oxygen, but act less as ferments when thus growing; they act most as ferments when forced into an anaerobic condition where they require oxygen, but are cut off from their natural supply from the air, so in order to obtain what they need for their development they seize the oxygen and wrest or tear it away from those molecules which contain it. As sugar contains a large per cent. and is itself a most excellent medium for propagation when present with nitrogenous mater, it falls a prey to these aerobic germs which have been forced into an anaerobic condition. The fermentation in this case is much more violent, and the pressure of gas formed in that fermentation is sometimes very great, exceeding 50 pounds to the square inch.

We thus see that packers who are pinning their faith to a a vacuum are depending upon a broken reed. *A vacuum has no value whatever in preventing fermentation*, and we can *truthfully state that it is a good condition for fermentation.*

A very pretty experiment to show that a vacuum is not a necessity for preserving goods can be made by puncturing a sterilized can of corn. By holding a hot flame on the tin and punching a very small hole with a hot punch directly through the flame, the vacuum will draw in enough air to fill the space; the air which is drawn into the can will be pure, as all the spores of bacteria which are in that air will be destroyed by the flame. The can must then be sealed while the flame is still on the spot, and the can will keep just the same as if it still possessed a vacuum. This proves two things: first, that the vacuum was not necessary for the prevention of fermentation, and second, that the air when pure and free from live spores will not cause fermentation. By puncturing another can with-

out the flame as a germ destroyer, it will be demonstrated that germs thus drawn into the can will cause fermentation in a short time. If the can should be inoculated with spores of resistant forms of bacteria while the can is still hot, and after sealing and chilling, a vacuum will form at once, but if the can be incubated at 85° F. it will swell in a short time, which proves that the spores developed in the vacuum and that the fermentation was violent.

If a can of cool tomato juice be left open for a few hours and another can of the same juice be sealed tight, the first will remain apparently sweet as far as taste and smell is concerned, while the sealed can will ferment and swell. I have filled tomato juice cold into barrels and left some of the bungholes open overnight, while others I have bunged. In nearly every case the open barrels would remain sweet overnight, while those barrels which were bunged up would often burst before morning and the contents would be fermenting most violently. In the first case those germs which found a lodgment on the surface of the juice would take from the air the oxygen necessary for their development; in the second case, the supply from the air was cut off, so the sugar was broken up in order to supply the oxygen demanded.

A PECULIAR PHENOMENON, "SPRING BOTTMOS".

In the springtime it happens that springs will often develop in cans which have stood all fall and winter in vacuo. Sometimes these cans will swell and ferment, sometimes the fruits will remain perfectly good. Now the question arises, how does it happen that after so long a time this phenomenon occurs. We have seen cans of tomatoes opened and the seeds planted and they grew and the vines bore tomatoes, all this after the tomato had been processed in boiling water.

The solution of this phenomenon is interesting from the fact that some scientific principles are involved, and which, when known, will obviate the trouble. If fruits which are processed in the fall and in the cool weather be not perfectly sterilized, there may remain the spores of some varieties of bacteria which will not develop in the cold weather, but when the warm days in the springtime come, the temperatures become more favorable for the development of the dormant spores, and fermentation soon sets in, which spoils the goods. In the cases where springs occur without spoilage, the phenomenon is due to the cell-life of the fruit itself, which has not been destroyed in the process.

A tomato, a peach, a pear, a plum, or any fruit, is just exactly the same in nature as a germ. The fruit is a large cell with living protoplasm and has the power of setting up alcoholic fermentation just the same as the saccharomyces, only far more feebly. Fruits and tomatoes which have been heated only enough to kill the bacteria which are on the outside and in the liquid portion, have not been killed themselves, and so when the temperature rises in the springtime they evolve a small quantity of gas and set up a feeble fermentation from their own vitality. If we place a whole tomato, which has been washed perfectly clean, in a nutrient sugar solution and sterilize only enough to kill any bacteria which may be in the fluid or on the outside of the tomato, and then incubate the can at 85° F., the sugar will ferment slightly and an appreciable quantity of alcohol will be formed, together with some carbon dioxide.

After removing the tomato we will find that it has lost some of its own sugar and the seeds will all be alive, and will grow if planted again. A fermentation of this kind will never be very violent, and seldom goes on for a very long time, because the conditions for the development of the tomato are not perfect. If the medium and conditions were favorable for new tomato plants to start, we have no doubt that many of the phenomena peculiar to bacteria might be observed in this large vegetable cell. We do see these conditions going on in the ground, but never in a pure form, as the fruits fall a prey to common bacterial life at once and only the seeds are left to sprout, while the surrounding protoplasm has been decomposed by bacteria. The whole fruit then must be called a cell, with the seed representing the spore life, and the surrounding meat is the living protoplasm, and the skin may be likened to the cell wall of a bacillus. Where the temperature in the sterilizing process has been raised to 240° F. for only a short time, this cell life is generally destroyed, and it should be in order to prevent springs.

GENERAL PRECAUTIONS AND CLEANLINESS.

When the canning products are brought into the factory, they should be placed in a cool, shady place if possible, or at least where plenty of air can circulate between and around them. Farm products should never be placed too close together. If corn comes in faster than it can be handled, it should be spread as much as possible, so that plenty of air can circulate between the ears. Tomatoes should be piled in boxes with sufficiently large openings between the slats. Any product whatsoever should have plenty of air circulation. Of course, it is better to work it up as fast as it

comes in, and the capacity should be increased to take care of it at all times, even if some machinery is idle part of the time. No goods should be carried overnight to give a start in the morning. The tendency is to carry too much overnight, and often on account of limited space it happens that proper circulation cannot be given, and fermentation and mold will quickly develop when the nights are hot. It is far better to compel the farmers to get their products in early, and if any stock is to be carried overnight, let them do it. Out in the country it is generally cooler than in the factory, and the farmer can spread his product and deliver early in the morning. Meats, fish, etc., should be kept in a freezing temperature at all times before the canning process begins.

Speaking of fermentation starting when products are not allowed proper circulation, shows us again clearly one of the great principles in bacteriology. When the circulation of air is cut off, the product is in an aerobic state to a great extent. The germs which are all over the product, being cut off from free atmospheric oxygen, will wrest the oxygen from the product to gain development, and the energy of the change of this oxygen from one set of molecules to another is released in the form of heat, which can be seen at all times where these conditions exist. Probably the first germs to act in this manner are the molds. The little plants cause no perceptible fermentation where the products are piled for only a short time with plenty of circulation, but when the air is cut off the little bead-like forms called conidia will start the fermentation very quickly, and these conidia will cause a great deal of trouble if they get a good start, and the haste required to save the product and the canned goods is often inadequate to prevent souring during the canning process.

Another fact we must not overlook in this connection is that when the products are allowed to become heated, which is an evidence of fermentation, the natural sugar is being fast converted into acids, and of course the quality is injured.

It will be remembered also that we have discovered that fruit and vegetables are themselves similar in characteristics to bacteria, although not so strongly capable of causing fermentation.

When these fruits and vegetables are piled closely together they will have an action upon one another similar in many respects to alcoholic fermentation, and it is for this reason that our California fruits are packed in sawdust or papers, so that they will not come in contact with each other. With some fruits this action is very slow, but in succulent fruits and berries the danger of fermentation is very much greater.

All waste material, such as cobs, peelings, cores, seeds, etc., should never be allowed to stand near the factory and ferment, because the air in the vicinity will fairly teem with the spores of the very forms most inimical to product which is being canned. We know that even in the purest air the numbers of the various ferments are very great, but we can realize how much greater in numbers they will be if this fermentation goes on close to the factory. Whenever a disagreeable odor is present near a canning factory, it is evident that putrefaction is going on, either inside or close by, and if the odor is perceptible, how full must the air be of these bacteria. The air ordinarily contains great numbers of the common ferments peculiar to every kind of product, but it is evident that the fewer forms there are present the less risk is taken in the canning of those products.

Mold is one of the most common forms to be seen around canning houses, and it is hard to keep out, too. It will be seen growing on the floors and walls, on the tables and wooden portions of machinery, and when we think of the myriads of the little conidia, resembling dust, which are blown hither and thither by every draught of air, we cannot overestimate the value of precautions against them.

Whitewash is a good purifier, and should be liberally used, and at night it might be good policy to let some one close up the rooms and burn sulphur, the fumes of which combine with the oxygen in the air, which is so necessary for the growth of the fungus, and the result will cause it to die. In this manner, by constant care, a canning factory may be kept in very good condition.

We cannot overestimate the value of absolute cleanliness throughout the factory, and the carelessness so prevalent in many quarters along this line has brought a great deal of discredit on the business. It is a very common remark so often heard, "I would not eat any canned goods, because I have seen how filthy those canning factories are." Any packer who gives a visitor such an impression has done more to injure his business than a whole batch of sour goods.

It sometimes takes a wise man to see a twenty-dollar gold piece behind a nickel, but do you know that success is built upon farsightedness? Any man who is far-sighted enough to spend his money on soap and scrubbing brushes and labor to keep his place scrupulously clean, and advertise the fact, and invite people to visit and see it, will in the long run be the gainer by a large per cent.

From a bacteriological standpoint, cleanliness is a great factor

in preventing loss. Filth is decomposing matter full of bacteria, which, like the mold, is a menace to the goods in the process of canning, and certain time should be given each day for the removal of all that goes to make a place filthy and untidy. Not only should these precautions be taken in the factory itself, but all the people who are employed should be compelled to keep themselves clean and tidy. Such a place is a credit to the business, and if I could get every man to follow out these principles, the days of home canning and preserving would decrease very rapidly. Give the people the proof that your goods are clean and they will eat them.

"Cleanliness is next to Godliness" is an old adage, and you will find that care along this line will have a moral influence on all your help; the managers will be more on the alert, more watchful, and likewise the employees will be more careful even in their work, and the result will be that you will have less waste and less spoilage.

SOLDERING SOLUTIONS.

Almost all fluxes used in soldering have more or less chloride of zinc present, which is the best for general purposes, but care should be exercised in its use, because a small quantity allowed to get into the goods injures the quality and is poisonous to those who eat the goods. Mechanical arrangements are necessary to supply this in such a way as to prevent its getting inside the cans. It is quite easily detected and deposited by sulphuretted hydrogen, and each canner should have his goods examined occasionally to be sure that his goods are free. Oils of various kinds are used, and some patented solutions, but the most of these will show at least 35 per cent. chloride of zinc.

CHAPTER X.

ANTISEPTICS AND GERMICIDES. VARIOUS CHMEICALS USED AS SUCH.

The use of antiseptics is not to be recommended in the canning and preserving industries. There is absolutely no excuse for their use in canned goods at all, and only a very lame excuse for their use in other products, but as stated before, where the product might cause more damage to stomachs from its fermentable nature than the chemicals used to keep it free, a reasonable quantity might be employed without serious objection. The use of these chemicals, however, is generally condemned, and I will merely mention a few

of them, because the subject of bacteriology demands the study of the actions of chemicals on germ life. Chemicals are not always germicidal; in fact, very few have the power to kill the spores, but they do have the power of combining with the oxygen in the different molecules as to make it unfit for the vegetation of germ life. Salicylic acid is one of the best known antiseptics and is easily detected when used only in small quantities by its violet reaction in the presence of ferric salts. It is non-poisonous in small quantities, although liable to injure persons afflicted with organic heart trouble. It has also the medicinal power to relieve rheumatism and fermentation of the stomach, in which case it is neutralized with bicarbonate of sodium. It is also used in surgery, and the dry acid will prevent the action of germs in fresh wounds. The commercial article is made 97 per cent. pure from carbolic acid, or, more properly, by passing carbonic anhydride through sodium phenoxide (carbolated), heated in a retort, but is improved by substituting sodium phenol in place of sodium phenoxide, in which case all the phenol is converted into salicylic acid. At 311° F. it is converted back again into its components. Its chemical or atomical symbol is $C_6H_4(OH)CO_2H$, or simplified, $C_7H_6O_3$. The odor of carbolic acid is plainly perceptible when heated to 311° F.

There are many others, some of which are most deadly poisons to man as well as bacteria.

Carbolic acid, corrosive sublimate, hydrocyanic acid are among these. There are others which may have value for some things.

Formic aldehyde $C.H_2O$ is a volatile antiseptic. It volatilizes at 212° F. Phenol, thymol, permanganate of potassium, eucalyptol, benzoic acid, benzoate sodium, terebine, phenyl-proprionic acid, phenyl acetic acid, boracic acid, boroglyceride and sulphurous dioxide are among the most prominent antiseptics known. Some of these are extremely good for purifying utensils, floors, ceilings, machinery, etc., which are used in the manufacture of food products.

The liberal use of sulphurous dioxide around the buildings is a great safeguard against mold.

We have mentioned in other parts of this work the preserving qualities of creosote, salt and sugar.

The result of the application of these antiseptics is not always germicidal. As we have mentioned, they merely prevent the germs from vegetating, and this may be observed by transplanting in a nutrient medium free from antiseptics.

CHAPTER XI.

HISTORY OF CANNING. DISCOVERIES. APPERT OF PARIS. ISAAC WINSLOW OF MAINE. THOMAS DUCKWALL AND ALBERT FISHER OF OHIO. EARLY CAN MAKING. STEAM RETORTS. PROCESSORS AND MANAGERS.

The first we know of canning is that a Frenchman by the name of Appert, in Paris in the year 1810, discovered that it was possible to keep fruits in an air-tight package by boiling, and further history of his experiments is not available. In 1839 we learn that Isaac Winslow began to can corn and other products in Portland, Maine. He experimented largely, and for a long time did not succeed in keeping it from spoiling. He tried to experiment in cooking the whole ears, but was unsuccessful, and the cobs seemed to absorb the sweetness. He then cut the corn from the cob and boiled the cans in a wash boiler, but nearly all his cans swelled; only a few remained good, which gave him heart to experiment further. In 1843 he built wooden process tanks, lined on the inside with zinc, and made steam-tight, so that a moderate pressure could be maintained, but these experiments were not entirely successful Sometimes he would be unable to keep a single can. Along this line of experiments he proceeded, with only a faint ray of hope, for ten years, when he applied for a patent, which was allowed, after long delays, in 1862. At this time several men in the West began packing fruits and tomatoes, among whom were Thomas Duckwall and Albert Fischer, near Cincinnati, Ohio. Thomas Duckwall (who is the father of the author of this work) small way on a farm situated a few miles east of Cincinnati, in Cleremont county. He was eminently successful in keeping the various fruits and vegetables, which brought good prices at that time on account of the war. Meanwhile, Winslow was working away on his process of keeping corn, and a part of his application for a patent on his process may be interesting. He said:

"After a great variety of experiments I have overcome the difficulties of preserving indian corn in the green state without drying the same, thus retaining the milk and other juices, and the full flavor of fresh green corn, until the latter is desired for use. Instead of a hard, insipid or otherwise unpalatable article, I have finally succeeded in producing an entirely satisfactory article of manufacture in which my invention consists. I have employed several methods of treatment. My first success was obtained by the following process: The kernels, being removed from the cob, were immediately packed in cans and the latter hermetically sealed so as to prevent escape of the natural aroma of the corn, or the evaporation of the milk or other juices of the same. Then I submitted the sealed cans and their contents to boiling or steam heat for four hours. In this way the milk and other juices of the corn are coagulated as far as may be, boiling thus preventing the putrefaction of these most easily destructible constituents. At the same time the milk is not washed away or diluted, as would be more or less the case if the kernels were mixed with water and then boiled. By this method of cooking green corn the ends of the cans are bulged out, as though putrefaction and the escape of the resultant gases had commenced within the cans, consequently strong cans are required.

"I recommend the following method: Select a superior quality of the green corn in the green state, and remove the kernels from the cob by means of a curved or gauged knife or other suitable means; then pack those kernels in cans and hermetically seal the latter so as to prevent the evaporation under heat or the escape of the aroma of the corn. Now expose these cans of corn to steam or boiling heat for about one hour and a half and then puncture the cans and immediately seal the same while hot, and continue to heat for about two and one-half hours longer. Afterwards the can may be slowly cooled in a room at a temperature of 70^{0} to 100^{0} F."

During this time the canners in the West were continually experimenting with processes for preserving corn and peas. Various experiments made by Thomas Duckwall in his small canning house proved that corn and peas could not be kept satisfactorily by boiling the cans even for hours, and to increase the temperature became a problem which was solved by the use of calcium dissolved in the boiling water. Various temperatures were tried, and he found that by dissolving a certain quantity of calcium in a given quantity of water that 240^{0} F. could be maintained, and he was successful in keeping corn all the period that the Eastern experimenters were

having trouble. He also packed all kinds of fruit and berries, which grew in abundance on the surrounding farms, and was kept back only on account of the difficulties in obtaining tin cans, which were not manufactured except by hand, and in a very crude way. Dies for cutting out the tops and bottoms of the cans were made of cast iron, and the upper die was made on a huge weight, which was pulled up to a certain height by means of a rope, and by falling on the sheet of tin would cut out single tops and bottoms. With only such crude machinery for making cans, the output was comparatively small, but the prices were good and the small frame house began to repay him for his infinite patience in experimenting.

Between 1867 and 1878 the corn packers in the East had been canning corn by boiling the cans in water. They had not experienced so much trouble as Duckwall had encountered in the West, but were able to keep a large per cent. of their cans after five hours' boiling, which process was not successful in the West. The few manufacturers in Maine at that time suddenly had a very rough experience in 1878, when the entire output spoiled, nor were they ever afterwards able to sterilize their cans by the boiling process. Capital had been invested, and the business had been growing rapidly before, and now everything seemed to be lost. New locations were tried, longer times of boiling were given, but without avail; the corn seemed to have changed into a new product which would not keep. Some manufacturers sent samples to chemists for analysis to find out what caused the trouble, but the real cause not being known, they could not give the manufacturers any information of practical value, except that the spoiled corn contained small round globules which were not dissolved by boiling heat. In the light of modern research we cannot but give these chemists due praise, from the fact that Pasteur's germ theory was not generally known at that time and had few believers, even among scientists in Europe, so the reports of the chemists were remarkable from the fact that they were able at all to locate the probable cause.

In 1879 a certain manufacturer in Massachusetts adopted a new process. He first boiled the cans, then punctured the cans and finally gave them a cooking for one hour in steam retorts or process kettles at 240° F. This process proved satisfactory for a long time, with only occasional spoilage, due to carelessness in manufacture.

We must remember that the manufacturers at this time had no conception of the real cause of the trouble in keeping the corn, but looked upon the matter as a mystery, and whenever a processor found a method of heating the goods in any particular way, by

which he was more successful than others, he was looked upon as possessing secrets, or information on the subject of keeping goods, and these secrets he tried to conceal with a great deal of mystery. He watched the time of his processes with great exactness, and believed that one minute more or less would cause spoilage. The processors were in great demand, not on account of the actual knowledge they possessed, but on account of what knowledge they *seemed* to possess. These men had no true knowledge of their business, and very few of them, even to-day, possess that knowledge, but depend largely upon what they have been told, or upon experience. Experience is a good teacher so long as no new complications occur, but it has been demonstrated from the beginning of the business that these new complications are constantly arising, and old methods of sterilizing are not successful now. The time is now at hand when manufacturers see the folly of depending upon mysterious rules for keeping their goods, and the advanced education in science is letting a flood of light in on the causes of spoilage in the canning and preserving industries. Manufacturers want to know the reasons for processing goods certain lengths of time, and the necessities required for obtaining the best quality, and the rule of thumb does not satisfy them. The time is fast approaching when the demand will be made for men with a scientific as well as a practical knowledge on this subject, so that it now becomes a necessity for processors and managers to take up the study of the science of bacteriology and apply that science to their work. The study of this science is a difficult one, because it is a complicated study and so comprehensive that it usually requires the rudiments of a higher education to enable the student to get the full value and meaning of what he reads and sees under the microscope. Then again, there are so many branches of the study that would not have a direct bearing upon this line of business, so that it would require a great deal of study in all directions to enable the student to pick out the points which would be advantageous to this business. These points have been gathered, and the observations made are of particular value, both to the manufacturer and the men who manage the work, and any one who does not desire to make a comprehensive study of this science will find that the main points have been pretty well covered in this work.

As there is a general lack of knowledge on this subject among canners, and a great deal of misrepresentation by certain classes of men who are doing the work of managing and processing, and as there is a great misunderstanding of the principles and char-

acteristics of bacterial action, this work will be instructive, first to the manufacturer who wishes to become more thoroughly acquainted with his business; secondly, to the managers and processors, who will do their work with a definite understanding, and the result will be that we shall have purer, cleaner and more wholesome goods than ever before, and this result accomplished with less loss from spoilage.

CHAPTER XII

METHODS OF CANNING.

The canning of sugar corn is one of the largest industries in the canning business, and the consumption of this one line alone amounts to more than 30,000 dozen daily, and within the last few years there has been great advancement in methods and cleanliness of carrying on the business, due in a measure to improved machinery for doing the work.

The varieties of corn now canned are the "Evergreen" and "Egyptian," which seem to be the favorite seed, because these varieties grow well and produce a good yield. Good sound seed are necessary to get a good yield and great care should be taken in the selection. Planting should begin as soon as the frost is out of the ground, and in order to get a longer season the planting should be made at intervals for six weeks following, but not later, as the yield is not good. Corn requires good rich ground, properly fertilized with bone dust or black manure, in order to get a well-developed ear and a good yield, and the weeds should be kept down and the soil worked to get good stout stalks.

When it comes time to pull the ears, this should be done in the early morning before the sun beats down upon the corn, the effect of which is to drive the sugar into the cob. No corn should be carried overnight to give a start in the morning, but it is the custom among many canners to do so. It is usually worked up as speedily as possible after it arrives at the factory, and the husking and sorting the good sound ears from the worm-eaten ears is the first operation. The unsound ears are trimmed and then the corn is passed into the cutting machines, which do the work quickly and better than hand cutters.

There are two methods of packing corn, and we will describe both methods, and the cutting machine will prepare the corn for either method, by simply adjusting the knives.

MOIST PACK.

In this method the cutting of the corn from the cob resembles the hand cutting, as the whole kernels are removed as nearly whole as possible by the knives at first cutting, leaving very little scraping.

After the corn is cut it is passes through a wire-screened machine called a "silker," which removes nearly all silk from the mass. After the silking process the corn is filled into the cans cold, so that the can will cut open full after it is processed. This requires some judgment, because it requires more corn when young than when it is a little old. It is needless to say that the young corn is preferable. Care should be taken not to fill the cans too full of the cold corn, as it swells out considerably in the cooking process. The cans are then filled with a weak brine, cleaned and capped, but not tipped. The next process is the "exhaust." The process consists in immersing the cans in boiling water, which drives out the air and heats the corn. After exhausting, cans are then tipped and delivered to the steam retorts or process kettles, which are fitted with steam gauges and thermometers, and in these tanks they are given either a steam or a water process under pressure to obtain a higher temperature than boiling. The amount of heat varies with different canners. After this process the cans are taken out and chilled in tubs or tanks filled with cold water, which stops the cooking process now going on within the can. This chilling process keeps the corn from turning dark or scorching.

DRY PACK.

This method of canning corn is very popular in Maine, and costs more than the other method, but the quality of the pack is better. The knives in the cutting machine are set so that the kernels are merely cut in the middle and the remainder is scraped off the cob by the scrapers adjusted in the machine. This part makes a pulp of the corn that is scraped off. After passing through the silker the corn is placed in a "corn cooker," of which there are several very good ones in general use. Here the grains and pulp are cooked and filled into the cans hot in a very cleanly manner without any slopping. After the cans are filled they are capped and tipped at once, and they are then put into crates and delivered to the steam retorts for the sterilizing process, and the treatment there and afterwards is precisely the same as with the "moist pack."

This method, while more expensive, produces a superior quality of corn, and the cans are more solidly packed. Canners cut

open some of their goods each day to ascertain if the cans are properly filled and not darkened by carelessness in the final process.

WHITENESS.

The demands of the trade have been for the canner to produce a whiter color in his corn, and so urgent were the demands that the corn which cut open a few shades darker than other brands could not command as high a price. The result has proved very disastrous to the canner. In order to get his corn as white as possible he shortened his time in the sterilizing process, and in some cases he even reduced the temperature. The consequence was that spoiled corn was prevalent everywhere. Many canners employed chemicals to bleach the corn, commonly sulphite of sodium, which produced the desired color and greatly injured the flavor. The shortening of the process and the lowering of the temperature endangered the goods, and the sterilization was accomplished by the use of germicides, such as salicylic acid. Here a new difficulty arose, from the fact that in the presence of iron this antiseptic would show its presence by turning violet or purple in color, and many are the packers who wondered why their corn turned purple. The exposed edges of the tin would furnish enough iron to cause the reaction in the presence of salicylic acid. Other germicides are also used, such as formic aldehyde, benzoic acid, benzoate of sodium, etc., etc., with the effect that while the goods might keep for a long time, yet the germs might not all be killed, and in the course of time would develop, causing the swelling months after; and in the next place, the flavor was more or less injured by the use of such reagents. Thus a great deal of poor corn flooded the market and injured the trade to the extent that few persons cared to run the risk of buying the article at all. The prices on corn fell rapidly, and it could be bought for almost any figure to get rid of it. There were many packers, however, who did not allow the popular clamor for extreme whiteness to influence their better judgment, so they continued in the old way, putting up the article with a view of obtaining the best quality and giving the matter of whiteness only the proper amount of care, which can be exercised in the best methods of canning corn. It is to these packers that the industry is once more on a proper relation with the trade, and the cry for quality became so strong that the use of bleachers and other reagents is rapidly coming into disfavor, even among former advocates.

SPOILAGE IN CORN.

The two methods for canning corn described a few pages back seem to read all right, but these are now in use and in certain localities the canners have been suffering severe losses, both from "swells" and "sour corn," and in order to study the causes and nature of these troubles, let us first understand just what is meant by the terms "swells" and "sour corn."

SWELLS AND SOUR CORN.

Swells are the results of pressure made from within the cans by various gases, such as carbonic acid gas, hydrogen, sulphuretted hydrogen, etc., and in the most of cases the cans are sour, although in several instances I have seen swells in which there was no sourness produced; however, these are exceptional and occur only where the fermentation was set up by the alcoholic ferments, such as the saccharomyces, cerevisiae and ellipsoideus, etc. In these swells the odor of alcohol was quite perceptible. These gases, which cause the swelling or bulging out of the ends of the cans, are the evidence of fermentation which is set up sometimes by a single variety of bacteria, but more often by quite a number of different varieties, such as the prodigiosi, amylobacter, butyrici, etc., which are found swarming in the anaerobic state within the can. The presence of these bacterial forms may be explained in this way: Either there is a small leak in the can, or else the sterilizing process was inadequate to kill off the spores which developed afterwards. Sometimes, where the leak is very large, the cans may not show by bulging out the ends, in which case the escaping fluids will be seen oozing from the hole through which the gases are also making their escape. If swells occur from leaks, there need be no alarm, but if a single can is found which swells without the presence of a leak, there is a reasonable doubt about the goods being properly sterilized. Often there has considerable time elapsed before swells make their appearance, in which case it is evident that the goods were nearly, though not perfectly, sterilized. If only a single spore remains alive, it may develop sooner or later, and if it does, the can will soon swarm with its kind. It thus happens sometimes that goods will appear all right for quite a time, and then after being agitated will swell. In this case it is a fact that some forms have not been killed and have been lying in a dormant condition, perhaps on the surface of the contents, so that when the can is agitated and the spore is submerged, the fermentation will be certain as a result of its develop-

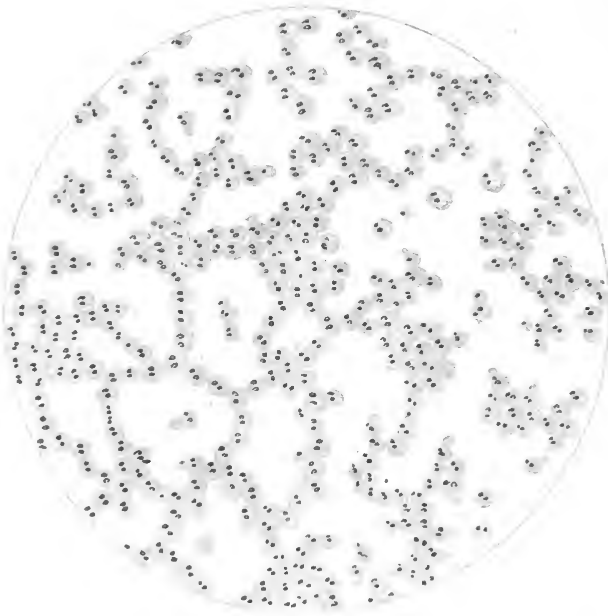


Figure 20

MAGNIFIED X 1000.

MOLD FUNGI. MONILIO CANDIDA AND ASPERGILLUS GROWING WHEN SUBMERGED IN CORN JUICE. DEVELOPMENT OF BUDS FROM CONIDIA.

ment. This frequently happens when the conidia of mold find a lodgment and are not killed by the heat. We have seen the housewife fill the fruit cans and seal them hot, and after a time have seen the mold grow on the surface, especially if the package happened to be glass. So long as the cans so filled remained in a quiet state, the contents would be perfectly sweet, but just as soon as the can was shaken sufficiently to submerge the mold film, fermentation and spoilage would result, because the mold would break up the sugar to obtain oxygen for its development, and thus resemble an alcoholic ferment.

Thus we see that goods do not necessarily swell in a short time after the final process, but it is usually the case if the final process does not sterilize the contents perfectly. Whenever the process is shortened and antiseptics are used, unless they be used in liberal quantities, there is danger of fermentation and swells in some future time. If the heating does not kill the germs and the reliance is placed upon the antiseptic, unless that antiseptic is very powerful, the spores are not killed. The effect of the chemical is a reaction on the oxygen which makes it unfit for the development of those spores. After a time, however, there may be a loss of power in the chemical, in which case the dormant spore will develop and the swelling of the can will result

"Sour corn" is a term often misused, but its real meaning is that the corn within a can, which has all the appearance of being good on the outside, is found on opening to be sour and nauseating to the taste. Cans of sour corn will never under any circumstances swell, otherwise they would come under the heading of swells.

I have opened hundreds of cans of sour corn and placed the juice under the microscope to see if there was any bacterial life. I have located the dead germs, but when transplanted to nutrient media I have never been convinced that any life existed, and when growth did appear, I was convinced after hundreds of experiments that they came from the air, and that the germs found in sour corn were dead. I found that some cans which did not show a swelled appearance at the time did contain various living forms, but when these cans were put in an incubator they would swell. The accompanying plate will show one view that I obtained from a can of this kind of corn. This example comes under the head of swells, and is not sour corn, properly so-called.

This is, of course, a view somewhat at variance with that recently given out by men who claim to have studied the subject, but their errors were made by not making a proper distinction between swells and sour corn.

Sour corn, then, is a trouble which we must locate in another part of the process of canning. It could not be due to any imperfection in the final process of sterilization, for in that case we could be able to induce a violent fermentation by incubation. But in the case of sour corn incubation has no effect. One thing may be observed at this point, however, and that is, that when these sour cans are placed in warm water they will bulge out slightly, but on cooling will draw in again. In order to explain this phenomenon we will undertake to locate the place where the souring occurred. You will bear in mind that the canners who have been losers from this trouble complain that a certain portion only of their pack suffered in this way. Some say, "I lost about 10 per cent. of my pack;" others say, "One quarter of my pack soured and the balance was good." These strange phenomena seem to throw a shroud of mystery around the trouble, but the strangeness of it all disappears when the light of understanding is turned on the causes.

The cause of sour corn is fermentation which takes place before the final process or sterilizing process. I want to impress this thought upon my readers, and the reasons for the statement. If the corn is not perfectly heated in the cooker and completely used out of it, so that none will remain at blood temperature in the cooker for any length of time, and if the cans are not quickly capped, tipped and taken to the final process, there is danger of sour corn. I have examined corn which came from the cooker in a house that was having trouble with sour corn, and I found that the corn was sometimes allowed to stand in the cooker for quite a while, waiting on the filling; that when the filling of the cans was going on faster than the capping facilities, some of this corn proved to be in active fermentation when being filled into the cans. I found also the same thing going on in the cans which sometimes accumulated ahead of the capping machines. The firm which was having the trouble had their capping machines get out of order frequently, and when this would happen the corn would get sour in the can, so that when it was sealed it enclosed an active fermentation and much gas. The presence of this gas will explain why the ends bulged out when the cans were afterwards placed in warm water. After the process the corn absorbed the gases which were sealed up in the can, and when heat was applied again these gases expanded, but in a short time would be absorbed again on cooling. All this can be readily seen and understood if the juice is examined under different conditions with the microscope, using a lens of 1000 diameters.

This study of sour corn under the microscope is very interest-

THE LARGE GERMS ARE SACCHAROMYCES. THE SMALLER CELLS ARE MYCODERMA VINI SUBMERGED.

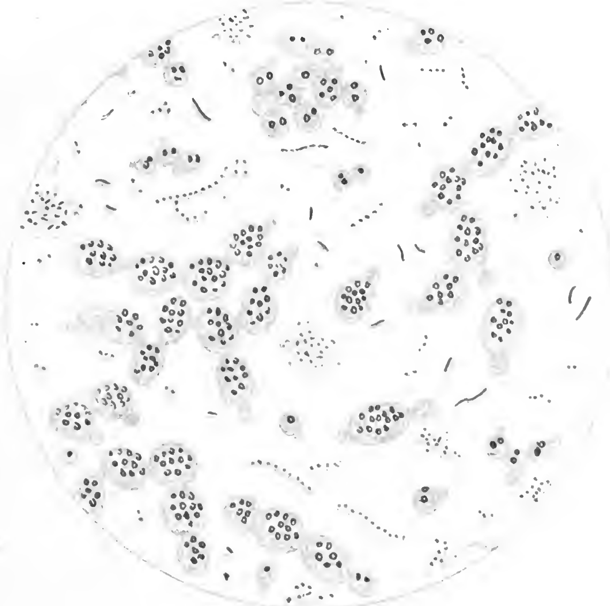


Figure 21.

MAGNIFIED X 1000.

THE CLUSTERS ARE AMYLOBACTER AND LACTIC MICROCOCCI THE SMALL RED DUMBELL MICROCOCCI ARE BLEEDING BRAST CALLED PRODIGIOSI. THE INTERIOR OF THE SACCHAROMYCES REPRESENTS THE SPORES IMBEDED IN THE PROTOPLASM. CHAINS ARE MYCODERMA ACETI.

ing, as the various ferments described in the former part of this work, viz: Prodigiosus, butyricus, lactic bacillus, amylobacter, mold, yeasts or saccharomyces, and an infinite number of various other forms which we have not classified nor described, are seen, and we can become familiar with their destructive power.

STERILIZATION.

In order to determine just what degree of heat would be necessary to kill all the bacteria in a can, I subjected numbers of cans to various temperatures and these experiments were made both with corn in the regular canning—that is, just after it came from the cooker—and also with cans which I inoculated with various ferments and molds. These experiments are very interesting and will give the experimenter a splendid idea of the requirements necessary to keep corn. The following diagram will give some idea of what occurred with each experiment:

Can Corn	Time of Boiling	Result		Time	Tem.
3 cans	1 hour	All spoiled		10 hours	80° F
3 "	2 hours	" "		"	" "
3 "	3 "	" "		"	" "
3 "	4 "	" "		24 "	" "
6 "	5 "	4 "	2 kept	2 Days	" "
6 "	6 "	" "		24 hours	" "
6 "	7 "	" "	various times	1 Month	" "
6 "	8 "	5 "		2 Days	" "
6 "	9 "	3 "	in 24 hrs.	1 Kept	
		2 "	" 3 Days		
6 "	10 "	1 "	" 24 hrs.	5 "	

The results were indeed surprising, because two cans kept all right by boiling for five hours, and in the experiment the next day at six hours all spoiled. This was, no doubt, a result of the two cans being free of the more resistant forms of bacteria. In some cases the cans did not swell until nearly a month afterwards, which, no doubt, was due to the presence of very weak growths of bacteria or forms which had nearly succumbed to the boiling temperature.

I found that a great per cent. of those cans which were boiled for ten hours would keep all right, but, as will be seen, one can did not, and a following experiment for the same time did not do so well. The sterilization of corn, then, by continuous boiling is not a safe method, as the spores do not perish at boiling temperature.

I then made careful experiments at 220° F., and the following

table prepared, giving the time of processing with live steam and the results will be interesting:

No. of Cans	Time	Results after Incubation at 85° F
3	1 hour	All spoiled in 24 hours
3	2 "	2 spoiled in 24 hours. 1 in two days.
3	3 "	All remain sterile.
3 others	3 "	All spoiled in 24 hours.
5	4 "	4 spoiled. 1 kept.
5	5 "	4 kept. 1 spoiled.
6	6 "	5 spoiled. 1 kept.
7	6 "	4 " 3 "
5	7 "	All spoiled in 24 hours.

The above experiments were made when the weather was very warm, and the results are not very flattering in the temperature of 220° F. We notice the same peculiarities in these experiments, where certain cans would keep and others would spoil at the same temperature used and to all outward appearance were exactly alike, the difference, of course, being that in one lot there were spores of more resistant power to heat than in others. These results of course, prove that 220° F. is not a sufficiently high temperature to sterilize corn.

We cannot but marvel at the wonderful resistant power of these spores. In the experiment in which the temperature of 220° F. was registered throughout the contents of the can for more than six hours, I found that the spores of one or two varieties were not affected in the least, and I made a microscopical examination of several cans after they had begun to swell, and I found nearly pure cultures of the bacillus amylobacter. In some I found the bacillus latici acidi and other rod-shaped bacteria flourishing. In one can I found a very nearly pure culture of the bacillus prodigiosus, but no evidence of any red pigment. These bacteria I transplanted to plates and they formed in a short time colonies which showed the red pigment very plainly.

I then made more experiments, using a temperature of 230° F., and the results are here given:

No. of Cans with Letters	Time	Results after Incubation at 85° F
3 Cans A. B. & C.	1 hour	A spoiled in one night, C in 4 days
2 " ' '	2 "	Both spoiled
3 " ' ' & C.	3 "	A and B kept. C spoiled
4 "	4 "	3 kept. 1 spoiled
4 "	5 "	2 " 2 "
4 "	6 "	All "
4 "	7 "	3 " 1 spoiled
4 "	7 "	All kept
4 "	7 "	3 spoiled. 1 kept. 1 leak.

The above experiments were made during a very unfavorable condition of the weather. It had been raining for several days, with the thermometer ranging from 90° to 100° F., so that the conditions were very favorable for fermentation. I made other experiments at 230° F., which were pretty good. A large per cent. of these experiments kept after three hours' heating. The unfavorable conditions, however, are the best tests, because the results would be so very damaging to the canner if his goods were processed by such an unsafe method. I made several microscopical examinations of the cans which broke down, in these experiments, and obtained almost pure cultures of several spore-bearing varieties. One variety was the bacillus viscosus, which was flourishing in one can along with several rod-shaped bacilli. No doubt a great many other forms had been killed by the heat, but these varieties still remained alive. The bacillus viscosus was not surrounded by any envelope when I first examined the juice, but after a few hours I noticed a slimy, ropy appearance; that is, I could dip the needle into the fluid and lift it in long threads like mucilage. I examined some of this fluid again and I found the germs entirely surrounded by an envelope and in masses so thick that it was hard to get a good view without diluting the juice with water. The most of the samples examined had a most foul smell, not exactly like sulphuretted hydrogen, but similar to it, and this was caused by the various putrefactives, among which was the bacillus fluorescens putidus and prodigiosus.*

I found that a temperature of 240° F. was very destructive to nearly all of the spores, but there were many cans which fermented even after two hours at this temperature. After three hours, I have never seen a can of corn spoil from the spores which naturally find their way into the corn during the process of canning, but this long time discolors the corn quite a good deal, and for this reason could not be used. I have inoculated cans with the spore of several varieties, among which were the spores of bacillus subtilis and lactic acid bacillus, which were not killed, even at that temperature, always. Experiments in processing for one hour have not been satisfactory, as many cans would break down and ferment. Experiments with a temperature of 245° F. for one hour have given fairly good results, and for one and one-quarter hours I have been successful in keeping corn all right, but the color was somewhat darkened. The best temperature for sterilizing corn perfectly is 250° F. for not less than fifty-five minutes, which I have always

*It will be well to refer back to the description given the organisms.

found to be sufficient to kill all the spores, excepting where the cans had been inoculated with the bacillus subtilis, in which case the results were not so satisfactory. Several cans "inoculated with a pure culture of bacillus lactici acidi also fermented after this process, but after one hour these failed to develop. It requires at least ten minutes' actual heat on the spores of this germ at 250° F. to kill them. These experiments were made, however, with the germs which had resisted high temperatures previously and which had been taken from the cans and cultivated, so that they represented the most resisted high temperatures previously and which had been taken from the cans and cultivated, so that they represented the most resistant forms. One peculiarity about the lactic ferment when inoculated into a can of corn which has been previously sterilized, is the fact that it will not be killed when high temperatures are used, such as 250° F. for fifty-five minutes, and that it will decompose the corn without causing any swelling, by which the sugar in the milk of the corn will be split up into lactic acid without forming any gases. The chemical change is simple $C_6H_{12}O_6 = 2C_3H_6O_3$. Of course if any of the spores of the bacillus subtilis be present along with the lactic germ, hydration will take place by those forms, and the lactic acid will be broken up, setting free certain gases which will cause the cans to swell. The lactic germs are nearly always present in swelled corn, but rarely, if ever, are found acting alone, but these forms make the sterilization of corn difficult, because such high temperatures are required to kill them, and there is considerable danger of darkening the color, too, from the employment of high temperatures. The "dry pack" corn is very hard to heat up to 250° F., as it requires fifty minutes by actual test with a self-registered thermometer placed in the center of the can.

REGISTERED TEMPERATURES.

The corn coming from the cooker registers less than 200° F., usually about 190° F. A self-registering thermometer, sealed up in the middle of a can, and the can processed for half an hour, registered only 231° F., while the temperature of the retort registered 250° F. with fifteen pounds pressure. At 250° F. on the retort another can was processed forty minutes and the thermometer on the inside registered only 240° F. In fifty minutes another test showed 250° F., or the same as the thermometer on the retort. These experiments show that the corn is not a good conductor of heat and that all portions of a two-pound can do not receive the same amount of cooking. The outer portions next to the tin receive a

great deal more heat than is necessary for sterilization, while the center is fifty minutes in attaining the same heat.

From the very nature of the corn, I do not think any practical devise for agitating the contents will be successful, because it could not be depended upon to expose the central portions of the can to the heat; that is, I do not think that the corn can be successfully shaken while heating to throw the corn in the center of the can so that it will come to the outside, near the tin, where the heat is registered sooner. For this reason I predict a failure for the new agitation kettles now being tried. The corn is too solid in pack to be thoroughly mixed by any rotary motion. The best method for getting the heat to the center of the can more quickly would be to lengthen the can and decrease the diameter, which is a more practical method. However, corn which is properly handled in the final process at 250° F. for fifty-five minutes need not be discolored so much as to make any material difference. During the process the heat does not discolor the corn; it is when the cold air strikes the tin that the discoloration takes place, and instead of cold air, if cold water is substituted by flooding the cans while yet in the process kettle after the temperature has fallen to 220° F. on the thermometer, there will be no perceptible discoloration. The scorching is caused by the tin being struck with cold air, and energy thus set free scorches the corn. Ice is always coldest when melting; metal is always hottest when cooling, especially when cold air strikes it. The blacksmith will tell you how much easier it is to get burned by iron which is chilling in the air than by a very white heat. One sticks to the flesh and the other repels it.

A PERFECT STERILIZING PROCESS.

From what we have studied on the subject there are two or three very important conclusions we can draw with reference to the very resistant forms of bacteria and the method of killing these forms without injuring the quality of the goods to be processed. We know of at least one form that we cannot kill at 250° F., and for all we can tell there may be others. I am speaking now of the spores or undeveloped seeds, and dried-up forms which have not begun to vegetate. We have seen that when Winslow began his experiments he was able to sterilize corn at the boiling temperature when he applied that temperature for four or five hours. For some unaccountable reason to us none of the resistant forms of bacteria seem to have troubled him; if they had the spores would certainly have been just as destructive to his corn as it is to ours.

It may have been that these forms had not begun to attack sugar corn at that time, it having been cultivated in this country only for a short time. It is likely that the putrefactive bacteria which at this date are so hard to kill had been growing and developing on vegetables and decomposing matter of an entirely different character, so that they had to habituate themselves to this new product. This is not an uncommon observation, taken of bacterial life, as we frequently see this phenomenon in cultures on prepared media, where certain organisms start very slowly on one kind of substance, and then reproductions will flourish much more rapidly than the parent germs, because they have adapted themselves to the particular composition of that substance. But to proceed: After the boiling process had failed, and packers were losing all the corn they canned, a temperature of 240° F., with ten pounds steam pressure, was substituted and the time of cooking was reduced to about one hour. This process has been working successfully up to within the last ten or fifteen years, and in some localities is still successful, owing, perhaps, to latitudes where these organisms occur in smaller numbers in the atmosphere. But the fact is, this process has ceased to give general satisfaction, and a still higher temperature of 250° F., fifteen pounds steam pressure for fifty-five minutes, is now declared to be a perfectly safe method of sterilization. Looking at this matter from a historical standpoint, we would not be surprised if the time would come when even this extraordinary heat would prove inefficient. As we know that the bacillus subtilis, which is common in infusions of hay undergoing fermentation, we would not be surprised if this organism should habituate itself in corn. We must admit that if we should have to contend with the spores of this organism, whose proved resistance is over 300° F. that the heat we are now applying would have no effect whatever. I personally have never experimented to find out just what temperature would be necessary to kill these spores, but we can rely on the evidence of so eminent a scientist as Professor Tyndall, who admitted his inability to kill them by continuous heat at 300° F. for hours, not only in one experiment, but in hundreds. With this evidence before us we are inclined to think that Klein and others erred when they said that these spores could be killed by ten minutes' boiling at 120° C. This is not probably the only organism in the world which is so resistant to heat, and it is well for us to look ahead for a perfect sterilizing process, so that when the time comes when we are unable to keep goods by our present methods, we may have a perfectly reliable method to adopt. Nor do I think that we should wait until we are forced by losses, but we ought to begin

at once to experiment and devise practical ways of carrying on this perfect system.

We have been referring to the system discovered by Professor Tyndall, which is based on truly scientific principles and is called discontinuous heating. In order to understand this process and its effect on micro-organisms we must refer back to what we have studied on the vegetation of germs from spores. These small refractile bodies that are called spores are surrounded by two coats or coverings which, like asbestos, in their power of resisting heat. preserve the life within, except when extraordinary temperatures are used to destroy it. For an example we would refer to the mustard seed, which, in its dry state, protects the life within through four minutes' boiling. When these spores are placed in a suitable nutrient medium they begin to soften and expand, and the coatings give away like the bursting of a grain of corn when it sprouts, and the life within the spore begins to expand and is soon surrounded with a soft protoplasm so delicate and sensitive as to perish when even an ordinary boiling temperature is used against it. Just like the sprout from the grain of corn, the developing bacillus is sensitive to the heat. It is during this vegetative period that we can overcome the action of bacteria easiest.

If we boil our cans of corn for a half hour the first time and chill them to 40° or 50° F., and keep them at this temperature for a few hours, many of the spores will begin to expand without causing any fermentation, so that if we heat them again for half an hour so as to allow the can to receive 212° F. throughout its contents, all these developing spores will perish. After chilling and storing again, some more of the spores will develop, which will be killed in the next heating, and on the third or fourth heating they will have all perished, leaving the contents of the can sterile, and the corn will be almost as fresh as the green product and its whiteness never before equaled.

To the practical canner this system of sterilizing would seem to be almost out of the question on account of the extra expense connected with it, but I will say that the extra expense may be entirely overbalanced by the prices such an article would bring on the market. As I stated before, the time may come when this system will be the only safe method of sterilization, and when that time does come, those packers who have studied this method and experimented along this line will get all the best trade and prices which will repay them for the extra expense.

In order to carry on this work successfully, a cooling system similar in many respects to that employed by brewers will have to

be used—a number of cooling cellars chilled with ammonia pipes to keep the temperature down to between 40° F. and 50° F. If the number of boiling processes were four, of course three chill-rooms would be necessary, and also four sets of boiling or sterilizing tanks. It would also be necessary to have quite a large supply of cold water in order to chill the cans after each boiling process. When you think of corn being kept by the boiling process for a length of time not longer than two hours, and realize what fine flavor and white color it would possess, surely the experiment will be worth the while for those packers who are progressive and want to produce the best quality.

While speaking of quality, I want to say that the market never has enough really fine quality to supply its demands. It has a great deal more poor quality than it demands, and one case of poor corn is a worse drug on the market than ten cases of good corn at higher prices. The American people demand a good quality, and if they cannot afford to pay the price, they buy poor goods which they do not relish, and consequently do not consume. It is a trait of the American people that they will have the best quality even if it costs a little more money. I believe our packers ought seriously to consider this method and experiment along this line, and thus be prepared for emergencies, which the history of this business demonstrates will surely come. Referring to the present methods of packing corn, a few suggestions along the line of care would seem to be in order. As packers will no doubt proceed with the higher temperatures for the present, a few remarks on management will be beneficial.

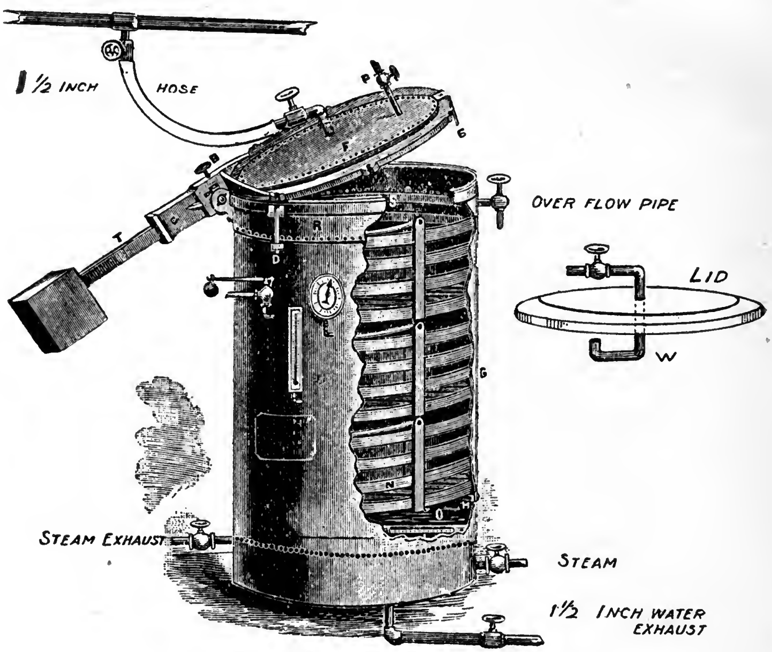
Corn should be pulled early in the morning of the day of delivery, before the rays of the sun drive the sugar into the cob from the kernals. No corn should lay overnight in the sheds, as fermentation begins rapidly, and a great deal of the natural sugar is lost by standing.

All cobs and waste should be removed from the vicinity of the buildings, so that the atmosphere may not become burdened more than ordinarily with the spores of bacteria, which would surely be developed on said cobs and waste. From the fact that spores peculiar to the micro-organisms which feed on corn are present in the shocks and on the grains of corn, it is a very necessary thing that after cutting the corn should be cooked as soon as possible to retard their action. After being cooked the corn should be filled into the cans hot and thus find their way to the final process as soon as possible to avoid sour corn, which disease occurs right at this point. The heating which the corn receives in the

cooker destroys all, or nearly all, developed bacilli, but if there should be a lapse of twenty or thirty minutes, those forms that were not killed would create considerable acid by their action on the sugar. Now if the can should be sealed in this acid condition, the result would be sour corn. I believe I have made this subject so clear that no doubt can hereafter exist as to the causes of this trouble. After rushing the cans to the final process the temperature, with dry steam, should be gradually raised to 250° F., with only a little exhaust, but enough to insure perfect circulation. If for any reason there should happen to be five or six inches of water in the bottom, from a clogging of the exhaust or otherwise, the cans would not be perfectly sterilized, even though the thermometer should register 250° F. throughout the process. The circulation in this case would entirely be cut off from the bottom row, and for several rows of the cooking would be very imperfect and the swelling of these cans would be a certainty. The upper courses of cans would likely keep all right, from the circulation of steam due to the pet-cock under the thermometer exhausting though only slightly. The danger, however, to the whole lot would be very great if for any reason the exhaust at the bottom of the kettle should become clogged. I have mentioned this feature of processing because I have seen the trouble happen, and the only remedy is to have a good, careful man in charge of this work, who would know from the actions of the kettle when anything of this nature occurs. After attaining a temperature of 250° F. with a liberal exhaust, the escape of steam maybe lessened by closing the exhaust all but about one turn, and the temperature regulated entirely by the steam valve for fifty-five minutes. When the time is up, turn off the steam and allow it to run down gradually to about 220° F.,when the cans should be immediately flooded with cold water before the lid is opened. An inch and a half water exhaust in the bottom must be opened at once and an overflow outlet near the top also. The diagram on the next page will also show how to operate these appliances.

The water line runs along back of the kettles and should be a two-inch line if possible. The connection to the kettle from this line should be made with a hose controlled by two valves, one at the top to prevent back pressure on the hose when the steam is on, and the other at the supply end. When the lid is raised the hose will bend, and this gives a direct connection of water through the lid for this purpose, viz: A spray, which is done by passing the pipe through the lid and then having an ell on this, then a short piece of pipe with an inverted ell, so as to throw the water against the lid, and thus spray the cans completely from the top. See

diagram W. Keep the water running until it overflows from the overflow pipe, when the cans will, no doubt, be chilled sufficiently to prevent darkening in color. This chilling process is a most satisfactory and successful means of preserving the color of corn which, under other circumstances, is darkened considerably when the cold air strikes the can on opening the kettle. The high temperature



does darken the corn just a little, but by using this chilling system a whiter corn will be obtained than by other methods where only 240° F. was used.

CORN TURNING BLACK IN SPOT.

This disease of corn has been the cause of much loss to packers, and from the nature of the trouble considerable mystery is attached to it. Within the last few years packers have been puzzled to find, on opening cans of corn, black spots here and there among the grains. Those who had been using chemicals for preserving the corn, and bleaches to whiten it, naturally attributed the

trouble to them, but when the same thing repeated itself when no chemical nor bleachers were used, the solution of the problem became very complicated.

Black spots are of two kinds, and the causes are two, viz: A bacterium called black torula, and the action of chemicals and tin. The first cause, black torulae, are bacteria of a black color and the product of their fermentation is black. The action of these ferments can often be seen right in the corn field where the ear has become bruised and exposed to the air, when a dirty tar-black substance will be seen to cover the kernels. It is the same organism that sets up the black rot in tomatoes and fruits. If these germs find access to the corn, they will form small colonies throughout the contents of the can and the spots will form if any delays occur between the cooker and the final process. The germs themselves are easily killed in the process, but their product will remain in the can. When the cause is due to the presence of these germs, the spots will be observed throughout the contents of the can and not alone around the outside edges. When the black spots have a purple tinge, they are due to the presence of salicylic acid which has had a reaction on the exposed edges of the tin. When the spots occur only next to the tin and are black, they may be accounted as coming from an action of the acid on the steel, due to a poor tin-plating. There are two processes of plating steel: one is a palm oil process, the other is an acid process, where the tin taken by the sheet which has been immersed in acid and then passed through rollers to squeeze the surplus tin off. Some mills leave only a shadow of plate on the steel, using as low as a pound and a-half of tin to plate a box of steel sheets. Under a magnifying glass this plating will appear porous and the steel is exposed to the action of the natural acid of the canned product. The acid starts on the steel, and of course the black spots will make their appearance. There should never be less than three pounds of tin used to the box and this tin should be applied to the steel in such a manner as to entirely cover it. The acid which is used as a flux is also dangerous to corn, and these difficulties due to poor tin-plate can all be obviated bya chemical quantitative and qualitative analysis. The spots caused by black torulae can be prevented by the oft-repeated instructions: "To make the greatest possible speed with the product from the time it comes in until it reaches the sterilizing process." The motto should be in the packing of corn: "From the field to the finished can in the shortest possible time."

PEAS.

Early June peas are planted from selected seed about April 15, and marrowfats about June 1. The yield per acre varies, but averages about fifty bushels per acre, producing about thirty dozen of two-pound cans. They should be picked in the early morning, and this should be done with all products which are canned, with no exception; and the reason is, that the product is fresher and will be sweeter if gathered before the hot sun beats down and drives back the sweetness into other parts of the plant. By numerous experiments this fact has been demonstrated, that during the night the sugar will follow the sap and the sun's rays will drive a great deal of it back again.

When peas are raised for canning they should be planted on ground close to the factory, so that they may be canned as quickly as possible after they are gathered. When they are raised in considerable quantities on level ground the vines are mowed just like grain and taken to the viner, which is a machine representing by its work the great genius of its makers and is one of the most wonderful inventions of the age. The vines are thrown into this machine and the clean peas are taken from the end free from bruises and clean to a remarkable degree.

After the hulling they are taken to a machine which separates the four or five sizes desired, which is probably the most important feature of canning peas. When the cans are cut open the contents must be uniform and the size must correspond to the wording of the label. According to the size as well as the quality, the prices are graded in the market, and it is needless to say that the smaller sizes bring more money.

After the peas are graded they are taken to the "blanchers" and scalded to get rid of the mucilaginous matter which covers the skin. The outside of peas offers a very fertile medium to the bacillus viscosus, which will set up fermentation if they be allowed to stand. The blanching process cleans and heats the peas through, after which they are filled into cans sometimes by hand, but preferably by machinery built for the purpose. These machines are made to graduate the quantity of peas for each can. It is a very important matter, this filling of the cans, in order that the cans may open with clear liquid, for if too many peas are put into the can the cooking will burst them and the liquid will not be clear. Right here I want to say that no packer should trust his goods to any machine without inspecting each step of the process.

Machines are built to fill, brine and cap goods all in one opera-

tion. This should never be done unless the goods can be inspected between each process. No machine does perfect work, however well it may be planned and built, and the man who trusts entirely to machinery without experienced help to inspect each process, is liable to have loss on account of poor quality, the result of imperfections. It is a far wiser plan to have separate machines for each process, and where peas are filled by machinery they should be inspected and doubtful cans weighed.

After filling, brining and sealing, with as much dispatch as possible, the cans are ready for the last and most important part of the work, the sterilizing and cooking process, which is done at a temperature of 240° F., with a time depending entirely on the nature of the peas. If the peas are young and tender, which should be the case if the business has received the proper care, this temperature maintained for fifteen minutes will both sterilize and sufficiently cook them without any danger of bursting the peas. Young peas will take this temperature in a very short time, as they are not very resistant to heat, like corn. Experiments go to show that 240° F. will be registered throughout the can in about ten minutes and all organisms which are peculiar to peas, the most common of which is the bacillus viscosus, will be destroyed. Marrowfats and old peas require about double the time that the young peas are given.

The peculiar, slimy and ropy appearance sometimes seen in peas is, like sour corn, due to the bacterial action between the blanching and sterilizing process, and this must be always the case where the cans are allowed to stand, due to overcrowding or unnecessary delays or breakdowns. The packer must understand that there must positively be no delays here, he must have reserve machines to avoid this in any line of goods he is packing.

Of course, if the sterilizing process is not sufficient, the can will swell, and if too long the peas will be overcooked and the liquid will be muddy. So great care must be exercised to get just the happy medium. Care must be exercised all along the line, and no packer should be without a competent manager, who is up on all these points. I might go even further and say that the packer should in the near future demand that his superintendent should have some knowledge of bacteria before trusting his capital to men without the proper knowledge to prevent loss. Under no circumstances should peas be colored, either by artificial coloring matter or by heating them in copper. If there is a demand for very green peas, be brave enough to say No. If peas are vined at the proper time, and speed and care used throughout the system, no color will

be necessary. They will open green enough in appearance and will be entirely free from poisons.

There is nothing which can bring discredit upon a business quicker than adulterations, and while the public demands that the product shall be a good color, by all means give it to them, but do not resort to artificial means. What the consumer wants, is not so much the color, but the standard. If the standard is good the color will be all right, and this is why the consumer wants the good color, because naturally it is associated with good quality. Canners have a great deal to contend with to please the trade, but in order to win for the industry the confidence and respect of the people, two things must be observed—honest goods and cleanliness of the work.

It is with the hope that many of the evil effects of the violation of these two points will be remedied that this work is given to the canner. We will uphold only honest methods, and to be exempt from spoiling, due to bacterial action, you must be very clean in the work.

TOMATOES.

It is not the purpose of the writer to give formulae for packing the various kinds of goods, only so far as the keeping qualities are concerned, because each packer has his own ideas of how he wishes to pack his goods; but the principle of keeping those goods are not always apparent. Some packers do not exhaust their tomatoes, merely fill, seal and process; others leave the vents open and then tip the cans before processing; others steam the filled cans before capping in steam boxes. In point of flavor the first method, no doubt, gives the best results, but the tomatoes must be rushed through quickly from the time of scalding to the sterilizing process, as fermentation begins very quickly after scalding.

The scalding of tomatoes is a very important feature of tomato canning. This should be done when the water is boiling and jumping, then it will scald the peel without heating the tomato to the center. If the water be not boiling hard, the tomato will be partially cooked and heated through before the skin will loosen. Frequently it will be noticed that a great deal of meat will come off with the skin, when the water was not at the proper temperature. If the tomatoes leave the scalder whole and firm, the skin will be easily removed and fermentation will not begin so soon. If the tomatoes be filled into cans promptly and processed at 240° F. for ten minutes, the sterilization will be all right, but the cans will not draw in as

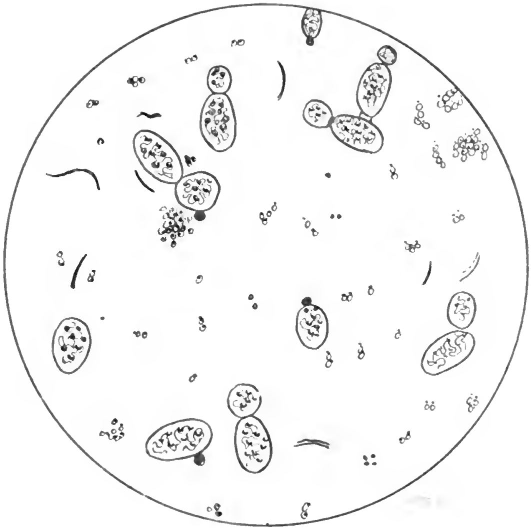


Figure 22

MAGNIFIED X 1000.

TOMATO JUICE FERMENTING.

SACCHAROMYCES, BUTYRICUS, PRODIGIOSUS AND LACTIC BACILLI.

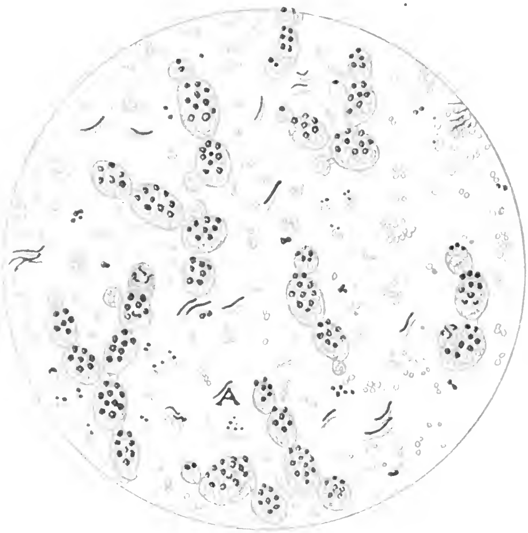


Figure 23

MAGNIFIED X 1000.

TOMATO JUICE FERMENTING.

A—IS A CHAIN MYCODERMA ACETI.

Same as No. 1 at 2.20.

rapidly as in the other system, where the cans were exhausted. If properly sterilized, however, the goods will keep and the cans may be snapped back to their natural shape by the boys who pile them. The tomatoes packed in this manner are very superior in quality and flavor, but require good management and dispatch in handling throughout, in order to prevent sour tomatoes, which, like sour corn, are most disagreeable in taste.

A very common method of packing tomatoes is in the use of steam boxes, where whole truck loads are pushed into them and allowed to steam for about ten minutes before capping. There is great danger in this method, especially if allowed to accumulate ahead of the capping machine, and two views taken of the juice which was thus exposed for over half an hour will be interesting. Fermentation started almost as soon as the cans left the steam boxes, and I made an examination about fifteen minutes after, and again in twenty minutes after that, and the development in that short time was marvelous. By comparing Fig. 22 with Fig. 23 the propagation may be observed in the case of each cell.

The great danger in allowing these tomatoes, which have been heated, to stand for any length of time is clearly seen by the microscopic views we have taken. We know that the result would be sour tomatoes if the cans should be processed while this fermentation is going on, for the acids formed would be sealed up, and also whatever gases were present when the cans were sealed.

Packers have often noticed that tomatoes would sometimes spoil if moved about from one place to another. This is probably due to the presence of mold conidia on the surface of the juice in the can, due to imperfect sterilization or perchance a slight leak when the fungus has started to grow on the surface, having been drawn into the can through the leak. As long as the fluid is not shaken the fungus will grow on the surface without causing any fermentation, and also keeping back any other forms which might happen to find a lodgment on the surface; but if the can be moved and shaken, the swelling is only a matter of a very short time, as fermentation will commence at once, with perfect resemblance to true alcoholic fermentation. The reason that tomatoes will spoil when agitated is nearly always due to mold conidia, and when they are heated and filled into cans at home, the air space will contain enough spores to start the growth of a pencillium on the surface. If the cans are carried to a dark, cool place and not disturbed, they will not spoil, but if shaken will ferment rapidly.

Tomatoes are used not only for canning, but in the preparation

of table condiments, such as soup, catsup, chili sauce, chutney, etc., and it may truly be said that the tomato is the most popular vegetable grown for food.

SWEET TOMATO CATSUP, CHILI SAUCE, CHUTNEY.

The tomato is a very perishable vegetable, easily attacked by bacteria, very susceptible to the growth of mold, on account of its sweet acid juice which forms a very large per cent. of its make-up. It is this juice which makes it so valuable for catsup purposes. The juice and meat of the tomato are forced through a screen and a commercial article called tomato pulp is preserved and sold for making catsup.

On account of the very fermentable nature of tomatoes, this pulp is hard to keep, except in hermetically sealed packages, which must be sterilized. On account of its being a good medium for the growth of the molds, such as aspergillus glaucus, pencillium mucor, racemosus, mycoderma vini and monilia candida, this pulp cannot be put up in hermetical packages without spoiling, unless these packages be given a sterilizing after sealing. It has been a very common method to add an antiseptic to tomatoes while cooking, and thus preserved, the juice could be sealed up hermetically and would keep fairly well, although not perfectly, as the antiseptic could not be used in quantities of sufficient power to destroy germs without injuring both the flavor of the goods and the health of the consumer.

Salicylic acid, which is a very powerful and tasteless germicide, has been used for this purpose, but the laws of several States have been made so stringent against its use on account of complications which made their appearance in some persons affected with heart trouble. By the use of this and other germicides, it was easy to barrel up the juice of tomatoes which could be kept and made up into catsup whenever it was wanted.

This tomato juice is made into catsup, which in its turn must be kept from the action of bacteria by some germicidal reagent, because it cannot, according to present methods of bottling, be made to keep, nor can it be sterilized because the cork would not keep out the germs. On cooling a vacuum of such power is produced that air is sucked in through and around the cork, and this air may have in it the spores of bacteria which will begin fermentation in the goods at once, unless it is armed against the attack with a powerful antiseptic.

Another reason why catsup and chili sauce are usually given

some antiseptic to keep them is the fact that when once opened these articles would either have to be consumed the same day or else kept on ice to prevent fermentation.

I have sealed catsup and boiled it for an hour and then covered the cork with sealing wax, but it would almost invariably spoil unless some germicide were used to make the oxygen in the contents unfit for bacterial food. I made an examination of some catsup I had tried to preserve without antiseptics, and the result was a formation of mold on the surface.

Indeed, I have found that molds are the chief obstacles in the manufacture of pulp, catsup and chili sauce without antiseptics, nor can their action always be prevented by the use of antiseptics unless used in very large quantities. The frequent losses to manufacturers in these lines will verify the truth of the statement.

During very warm days after rains, sometimes the molds will develop so rapidly on the tomatoes that they cannot be used up before the fungus becomes visible to the naked eye. The conidia are very resistant to heat and it is sometimes very hard to preserve catsup, chili sauce, etc., during such times, even with the aid of germicides.

Looking over the business as carried on; that is, by the use of antiseptics to keep the goods, I cannot but say that it is risky, because a quantity sufficient for the killing of ferments cannot be used without injuring the flavor of the goods and endangering the health of the consumer. Owing to the non-expansion of glass, bottles cannot be sterilized so readily as tins, so that the keeping of catsup, chili sauce, etc., becomes a problem.

The manufacture of tomato catsup from unfermented material is a very great industry at this time, and the formulæ in use by great concerns are proprietary and should not become public property. As different concerns have their own peculiar methods, which they consider better than others, any formula which might be suggested would be open to criticism, and it is not the purpose of this work to take up the different ingredients which go to make up any particular food product, but simply to point out the dangers from bacterial action and give the necessary precautions to prevent loss.

It is my impression that tomato catsup and chili sauce,

also chutney, can be put up without the use of antiseptics, which would no doubt give a better flavor to those condiments, but we must not overlook the fact that the consumer will have to be careful and keep these products in a cool place to prevent fermentation. When a good method of sterilizing these goods in glass is discovered, the dangers which beset the manufacturers who use antiseptics will be obviated to a great degree.

It is argued, in opposing the use of antiseptics in food products, that because nearly everything now prepared for table use is preserved chemically, so much may be taken from different articles of food at a single meal as to interfere with the natural peptonization of that food in the stomach during the process of digestion under the influences of saliva, gastric juice, bile and pancreatic juice. This argument has such force that laws have been passed in several States and European countries prohibiting the sale of such goods altogether, and in a few instances only when the packages are labeled "compounds," or "chemically preserved." It is hard to draw the line, however, because there are several articles which are preserved by antiseptics to which no reasonable man could object. Smoked meats are preserved from the creosote taken from the smoke, and we find that the honey bee preserves its honey by injecting formic acid.

I am inclined to think that in a general way antiseptics of certain kinds are not injurious to man, but I do think that there ought to be limitations only in the use of chemicals to such goods as cannot be kept free from the action of the bacteria.

For instance, in a chemical analysis of a great many varieties of canned goods by Government chemists, they discovered the presence of salicylic acid in nearly all. Every thinking man will agree that this is unnecessary for keeping goods packed in tin, because the simple sterilizing process was all that was required to keep canned goods. Salicylic acid was used in corn so that the corn might be whiter, because a shorter process would keep it when the germicide was present. It is the abuse of privileges which brings down the wrath of the law upon all.

While I think that it is possible to keep the most of goods without the use of antiseptics, I am not ready to con-

Figure 24
MAGNIFIED X 1000.
PENCILLIUM, ASPERGILLUS, GLAUCUS AND SOME OF THE CONIDIA.

demn their use in some cases, for it is vastly more injurious to the human stomach to receive foods which are undergoing fermentation than to receive foods which are free from that fermentation, even if they are preserved by small quantities of harmless germicides. The disorder to the stomach would be infinitely greater in the former case.

I have seen thirty grains of salicylic acid taken daily for a whole month without any perceptible inconvenience to the man, and, indeed, we might go still farther and state that foods chemically preserved are sometimes very beneficial to sufferers from stomach troubles, as they retard the action of foreign ferments and allow the peptonizing process to go undisturbed. Foods which cannot ordinarily be sterilized and kept are better if preserved with some harmless antiseptic, and we might include under this head tomato catsup, chili sauce and chutney, because after they are opened they become exposed to bacterial action, and the antiseptics would prevent this for quite a time at least.

CREAM OF TOMATO SOUP.

The canning of this article is quite extensive and the formulæ are proprietary, but from the milk used in the manufacture the loss occasioned is sometimes alarming. In this article, as well as other products where milk is used, the danger from lactic fermentation caused by the bacilli lactici acidi and bacilli cyanogeni, which give the blue color to milk, is very great.

When these organisms get a start the loss is generally complete, nor is their action perceptible until too late to save the goods. There is no swelling or bulging of the cans to indicate that they are at work, and it is only when their work has progressed far enough to be noticeable that it can be detected except by chemical analysis for lactic acid. These germs break the sugar into lactic acid without any other chemical change, and on account of the usual boiling process they are generally the only forms left, and consequently in almost all cases the work is accomplished by pure cultures. The boiling or sterilizing process will kill off all the ordinary forms of bacteria and only these will remain because of their great resisting power. Some packers have resorted to the use of germicides to keep this soup, because it appeared that it was not possible to sterilize it, but such is not the case; it may be sterilized in a short time under proper pre-

cautions by two methods, either the discontinuous process or 120° C. for fifty minutes. The organisms which cause this trouble are non-motile, and you would never suspect the terrible damage they were doing unless you knew the character of the organism.

OYSTERS.

The oyster beds in Chesapeake Bay cover hundreds of thousands of acres, and the dredging gives business to over fifteen hundred vessels and eleven thousand people, while those directly and indirectly interested are about one hundred and fifty thousand.

The packing of oysters begins in October and runs through the winter, finally ending about the last of March.

The oysters in shells are brought in fresh and steamed in steam cans, after which they are shucked, washed and filled into boxes by weight regulated by law. The cans are hot dipped, capped and given a heavy process of from ten to fifteen minutes at 240° F.

The only place where considerable care must be exercised in the packing of oysters is after they are shelled. If exposed to the atmosphere for any length of time, bacteria of a pathogenic nature may find a lodgment, and, if allowed to begin their action, will produce ptomaines. There is danger to a certain extent also with the oysters in the shell before steaming if they be not fresh and cold. No diseased oysters should be used, none that may be slightly tainted, for if these poisons are once deposited, or, more properly, produced, the results will be damaging in the extreme, may even cause the death of the consumer.

The word of warning given here is not ill-timed; there have been cases where packers of oysters have put up oysters which ought to have been buried and we frequently read of whole families stricken with terrible cramps and sickness as a result of eating contaminated canned goods. This is damaging to the business in general, and this warning should be sufficient to keep any man from willfully canning oysters or anything else which may have become contaminated.

MEATS AND FISH IN GENERAL.

There are many ways in preserving and canning these articles which have caused the growth of various mammoth

establishments to produce a supply sufficient for the demand. The canning of beef, sausage, clams, lobster, salmon, sardines, etc., represents millions of invested capital, to say nothing of the various other methods of preserving by drying, smoking, pickling, etc.

The canning of meats and fish of every description is easily done, and there will be no difficulty if they are fresh and rushed through rapidly after the first heating and given a heavy process, varying with different kinds of meat. Only the ordinary precautions are necessary as described in the sterilizing processes of other goods.

Probably no line of canned goods has caused so much trouble as the canning of meats and fish. There have been hundreds ot cases where people have been stricken down and died from eating canned goods of this kind, because of the presence of ptomaines. Meat is very susceptible, and fish even more so, to the action of pathogenic germs. Even meat canned from animals suffering with some disease may contain these tox-albumenoids, and it sometimes happens that unscrupulous persons will try to evade the law and will persist in canning meat which they know ought to be condemned. I know, personally, of one man who was arrested time and time again for trying to can meat which was wholly unfit for food. The dangers attending these cases are very great, and anyone who does try to evade the law should be dealt with in a very summary manner.

During the process of canning meats and fish, the dangers from ptomaines is very great unless everything is done with dispatch. The juice of meats is probably the most nutritious medium for the spontaneous growth of micro-organisms. Not only common putrefactive germs will begin action, but even pathogenic bacteria will thrive remarkably well and most rapidly, too, in a favorable temperature. Meat should always be kept very cold, which is an unfavorable condition for the propagation of bacteria.

One fact must stand out clearly to packers of meats and fish: "No amount of processing and no quantity of antiseptic will dispose of ptomaines after they have been produced."

Another method of preserving meat so that bacteria will not attack it is by salting. Salt, when used in sufficient quantities, will make the conditions unfavorable for the

propagation of bacteria. This method is carried on extensively by pork packers and fish packers, and the market for this class of goods is very large.

Another method of preserving meat is by smoking. This is also carried on with fish, such as herring, sturgeon, halibut and cod. The preserving of smoked meats and fish is the result of the creosote taken from the smoke by the meat. This creosote, together with the salt, makes the meat a poor medium for the propagation of bacteria. The danger from ptomaines in these smoked meats and fish is very great from any carelessness in handling the raw product. There was a time only a few years ago when the deaths caused from eating smoked sturgeon were numreous and for a long time the article was tabooed.

Another method of preserving meat and fish for a considerable time is by cold temperatures. Bacteria will not develop at the freezing point, and the great pork houses and fish depots are employing this method all the time in preserving their products, so that the consumer may get pure, fresh meat and fish.

The dangers in this line come from allowing the temperatures to raise during the handling and shipping of the product. Meat and fish will spoil very rapidly if the temperature is thus allowed to raise only a few degrees. By long exposure to the atmosphere in the cold state, the spore of putrefying germs, both pathogenic and non-pathogenic, have found their way into the meat, but will not develop so long as the temperature is freezing, but when the temperature does increase, through carelessness in handling, bacterial action begins at once, and perchance some forms may produce those poisonous alkaloids. Even if they are frozen again, the poison will remain, and we have read of many cases of poisoning from this source, principally where sausages were eaten.

Freezing is a method of keeping many kinds of goods milk, butter, eggs, cream, lard, etc., also vegetables.

Milk is a very dangerous medium for bacterial action, and no amount of after freezing will eliminate any poisons which may have been produced when it was warm. How frequent are the cases of tyrotoxicon poisoning from eating ice cream? The cause was the production of this tyrotoxicon or other ptomaines by such germs of cholera, tetanus,

typhoid or diphtheria bacilli, which may have started to develop on the fat of the milk; that is, the cream, when it was warm. Many dairies are very filthy in their methods, and they sometimes adulterate their milk with water from questionable sources. This water may be alive with disease germs which will find a most excellent nutrient medium in the warm milk. It is here, most probably, that the poison is produced in the cream, and the effects cannot be realized until the cream is eaten.

I have no doubt that we should hear of many more cases of this kind of poisoning than we do if it were not for the fact that so small a quantity of cream is used ordinarily at meal time, so that if the poison does exist the quantity which may be taken in the small amount of cream used in coffee might not be noticed nor cause any trouble, but it is generally seen by its alarming effects where larger quantities are eaten in the frozen form of ice cream.

Sugar is a great preservative in the manufacture of preserves where the amount used is far in excess of the nitrogenous elements. In this form it is very thick and does not yield readily to bacterial action, as the amount of nitrogenous matter which goes to make up the protoplasm of a cell is not easily taken up because the fluid is too thick.

Mold, however, will grow on things which are sugar-cured and exposed, but not so well where the substratum is thinner and more acid in nature. Preserves which are put in bulk are usually covered with some kind of parchment which has been bathed in an antiseptic solution of sulphur dioxide or something similar.

If preserves are put up with a thin syrup, it is necessary to follow the usual rules of sterilization by hermetically sealing and submitting to boiling.

Drying and evaporating are two methods of preserving founded on the principle of depriving the cells of bacteria of the necessary liquid protoplasm for vegetative purposes. Spores of all kinds may lodge on dried fruits and evaporated products, but they cannot grow because there is no moisture to swell the cells. The enemies of these products are worms.

PICKLES, KRAUT, ETC.

These products differ from almost all other products in that they demand a certain amount of natural fermenta-

tion before they are ready for consumption. The formulæ for producing the best quality are, of course, proprietary, and differ with different concerns.

The peculiar fermentation is brought about by adding enough salt to them, so that only certain kinds of bacteria will propagate. Too much salt will limit the needed fermentation, and too little salt will expose the products to the action of foreign ferments. The secret comes in using only the required per cent. in order to facilitate the action of one kind and at the same time make the medium unfit for the development of other kinds, which would produce diseases, known as soft pickles, spoiled kraut, discolored onions, etc. Probably the greatest enemies to these products are the different types of mold. A great deal depends upon the season, location, water, and temperature in producing the best quality.

SOUPS.

The methods employed to produce the fine canned soups vary with the different concerns who manufacture them, and the formulæ are proprietary, but there are some troubles experienced which can be cleared up by the application of bacteriology.

One of the most common troubles experienced is bitterness. The cans do not swell, but the soup tastes so bitter that it cannot be eaten. I was present when one concern had a great deal of this kind of trouble, and the cause seemed very mysterious. Every ingredient was examined for purity and seemed all right, but a few days after the soup would be intensely bitter and was a total loss. The cause was finally and very unjustly blamed on the cans. The manufacturer had been using a certain gasoline flux for soldering, and, while it was slightly bitter, it was not the real cause, as it would have required at least a tablespoonful in each can to have produced such bitterness as was present in the goods. At the time, I had not begun the subject of bacteriology, and the trouble seemed as much a mystery to me as to anyone else, but I never was satisfied with the theory of the flux as the cause, because other goods which went into these cans did not have the unpleasant taste.

The method employed by this firm was to get in large quantities of very poor meat, some of which was entirely

too poor for any purpose. It was meat which could not be sold in any other way, and the proper care for preserving it on ice had not been exercised. This meat was cut up and placed in large kettles full of water which were brought to a simmer and kept thus for eight to ten hours. The juices thus extracted would be spiced and flavored, then canned, sealed and processed at 240° F. for seventy minutes, which was a sufficient heat to sterilize cans.

The trouble came in the meat, which had been exposed to the action of a certain variety of bacteria belonging to the putrefactive class. I examined meat under the same conditions afterwards and found that all the bitter products were produced before the meat entered the kettles. The bacterium which caused the trouble I am unable to name, but am of the opinion that it belongs to the class of viscous ferments. It was a rod of from 2 to 4 μ in length and 1 μ in thickness which formed colonies in spots resembling the typhoid bacilli and were surrounded by an envelope of mucilaginous nature which gave a clammy and sticky sensation to the touch. The bitter product resembled that of aloes. The bitterness was so pronounced that all utensils used in the manufacture would contain more or less of it, and when the cream of tomato soup was made in the same kettles, it, too, became bitter and deepened the mystery of the causes at the time.

It is almost needless to say, that in the first place the meat was not the proper quality, and in the second place there was not sufficient care taken for preventing bacterial action, so necessary to avoid these complications.

SUMMING UP.

We have taken up the study of such forms of bacteria as are commonly met with in the destruction of food products, but we have not studied all the different forms, but only those which are best known and which have served the purpose of teaching us just what they are, what they look like under the microscope, and how they act under different conditions.

We have taken up the most important branches of canning and preserving, being careful not to lay down any iron-clad rules or formulæ, but with a view of simply applying our knowledge in bacteriology in a practical manner to

obtain the best results with a minimum loss. By studying the applications of this science as applied to those branches, it will make the way clear for the application to any kind of canning and to any kind of product.

We have learned that bacteria are the causes of all spoilage, that they come from the air, that they demand certain temperatures to destroy them. We have learned how they develop and on what they particularly thrive, under what conditions and in what temperatures.

The mysteries have been cleared up to a great extent and the necessary precautions have been carefully laid down for preventing loss.

To the man who intends to take up this science and study it with a view of applying its principles to his business, the work that we have taken up in these pages will open up the way and give him a pretty good foundation.

I would recommend that every packer and preserver should fit up a room in a suitable part of his factory, with a microscope and all the necessary attachments, also tubes, flasks, plates, an incubator, etc., and there begin to learn for himself just what kinds of bacteria are peculiar to any product he intends to pack, and observe their action and note their resistancy to heat, and the action of different germicidal agents on them. The value of a practical knowledge of this science cannot be underestimated, and the points which do not seem clear to him in the text will be clearly demonstrated by actual observation.

We cannot foretell what new sterilizing agents may be introduced in the future, but we have every reason to believe that electricity will sooner or later be the best power for the purpose. We have considerable evidence that the X-rays are germicidal. Just how these rays affect bacteria we cannot say, but we would compare the rays to shot from a gun. These rays have great penetration and are so fine and close together that they seem to shoot through even wood, and we can imagine that bacteria will be shot by them and affected in such a way as to stop their vegetation.

It is a fact that even the leucocytes of the blood, which are the white corpuscles, are destroyed when the powerful X-rays are turned upon living tissue. There have been cases where flesh has become perfectly dead after being exposed to high power.

The time may come in the future when a machine may be contrived that will send the rays through canned goods in such a manner as to kill all bacterial life within the can and the product would remain as fresh as when put into the can. As I stated before, we cannot tell what improvements may come, but we know that the scientists are working and experimenting along this line to destroy disease germs, and if the canner and preserver keeps pace with them by keeping up his studies in this direction, he may be able to adopt for himself the very latest discoveries, and he may apply the principles in his own work.

I speak of electricity as a possible power to accomplish sterilization and this idea is held by a great many who are using it in their laboratories. I have experimented a great deal with both straight and alternating currents of various voltage and am convinced that the action of the electric fluid on the carbon in the molecular construction of any goods is such as to make it poor food for bacteria, but have not been able up to the present time to prevent scorching.

I have taken the positive and negative wires and fastened platinum strips to the ends, and, being careful not to let them come in contact with each other, I have placed one end in the centre of a jar of fruit juice and then made a circuit around this with the other wire. Of course both strips would heat white hot during the experiment, but the current would pass through the goods and its action was such as to make the juice unfit for any bacterial life excepting mold on the surface.

I merely state this to show that electricity has some germicidal action, but on account of the crudeness of the experiments and the lack of definite knowledge on this subject, it has no real value at present further than to give us an idea.

For the present, then, we are simply confined to those methods of sterilization which have been discovered and tried successfully by the most eminent scientists of our time. We can continue to study and apply the principles, and our knowledge will always be a safeguard against any severe loss.

If these pages have cleared away any of the clouds of mystery surrounding the troubles of canning and preserving, and have opened up the ways and means to prevent loss, the writer will feel fully repaid for the long hours of tedious study devoted to the work.

FINIS.

STERILIZATION IN CANNING.

BY EDWARD W. DUCKWALL,
AUTHOR OF "BACTERIOLOGY APPLIED TO THE CANNING AND PRESERVING OF FOOD PRODUCTS."

The primary meaning of Sterilization is barrenness, and has a suggestion that the application of heat is necessary to accomplish that result. We use the term in canning to designate the final cooking process which is commonly believed to kill all life within the can. The life here meant is bacterial and vegetable life. There are many peculiarities about the sterilizing process.

The question is often asked, why is it that peaches, pears, cherries, apricots, etc., will keep, when given a process of 250° F. for one or two minutes, and tomatoes, corn, and peas will invariably spoil, especially corn, which requires almost an hour? Why are the bacteria in cold pack tomatoes killed when processed for fifteen minutes at 250° F. and those in hot pack corn will not be killed in that time, when the spores of the very same germs are found in both? Why will some goods keep when processed in open bath, while other goods will not keep except they undergo a process for a much longer time at a higher temperature? If we take four sound cans of corn and tomatoes and punch a hole in each, the vacuum will draw in about one cubic inch of air or perhaps less; and if we reseal and give them a light exhaust, then process in the open bath for thirty minutes, the corn will spoil, while the tomatoes will keep. Why is this? Surely the tomatoes received as many varieties of bacteria through the puncture as did the corn, yet the one will keep and the other will spoil.

In order to answer these questions, it is necessary to understand the nature of bacteria and the requirements necessary for their propagation. We know that certain varieties of these microscopical plants require certain kinds of food for their propagation, which may not be suited to other

varieties. We find this to be true in the higher vegetable kingdom; if we visit the sandy wastes of Arizona and New Mexico we will find the cactus growing under conditions that would consume the delicate Rose and beautiful Lily of the Valley; if we visit Alaska and Greenland we will find the evergreens flourishing under conditions that would freeze the palm and orange trees of Florida; we find moss growing on rocks where potatoes could hardly find a lodgement. So we may look for certain characteristics of this kind in bacterial life.

We find a certain class of germs flourish and propagate on sugar combined with moist nitrogenous matter. These germs will convert the sweet juices of fruits or any other sweet infusions into alcohol, succenic acid, glycerine, carbonic acid gas, etc. Some will convert the sugar into acids at once, but usually another class of bacteria which feeds upon the alcohol which has been generated by the Saccharomyces from the sugar, and those bacteria convert the alcohol into lactic, acetic, malic, or butyric acids, etc., according to the particular nature and kind of bacteria they happen to be. Then there are still other varieties which take the fruit acids and feed upon them, converting them into more simple or fatty acids.

For example, if we take some of the milk of sweet corn and inoculate it with a pure culture of Saccharomyces or yeast and keep the infusion at a temperature of 34° F. (as this is the only class of ferments which will propagate at so low a temperature), the sugar in the corn will be converted into alcohol, etc.; then if we inoculate further with the Lactic Acid Germs, Bacilli Lactici Acidi, and increase the temperature to 85° or 90° F., the alcohol will be converted into lactic acid, and if any sugar remains, acetic, malic, or butyric acid may be a result of some germ acting on the lactic acid, but usually the conditions are more complicated than this, and when we increase the temperature from 34° to 90° F. it is a favorable time for any number or the different varieties of bacteria to thrive, and thus we would be able to observe the work of breaking down, begun by various fermentive and putrefactive agents. The chemist could, after a couple of days, find any fatty acid known, as a result of the combined bacterial action.

Peaches, pears and cherries and succulent fruits are sus-

ceptible to the action of a variety of bacteria, prominently Saccharomyces Apiculatus Cerevisiæ and Pasteurianus, which have very little resisting power against heat, so as soon as the temperature reaches a certain degree they perish, but not so with many other varieties present. These may in the course of time succumb to the starving process or the antiseptic influence of the fruit juices, but so far as the heat is concerned they are able to live through it, but unable to develop into mature forms from their spores, because the medium or substratum is unfit for their food. If perchance, however, the first variety should survive an insufficient cooking and should set up a fermentation, then these other varieties might find a suitable medium in the products of that fermentation, but experience has taught us and the microscope reveals to us that the material and conditions are not suitable for their development and when the Saccharomyces, etc., have perished by the heat, so they remain dormant or the fruit acids kill them ultimately.

Bacteria spores are not the only forms of life which may sustain a light process. Strange as it may seem, the seeds of some of these fruits will grow, if planted even after the cans have been processed. I have seen tomato vines grow from the seeds in cans that had been processed the year previous, also a cherry tree grown from a seed thus.

Now there is a trouble often experienced by canners which seems unaccountable to many and is commonly experienced with canned fruits, such as cherries, peaches, pears, etc., viz: Spring Bottoms. This class of goods, as we have seen, is given only a light process, and we also learn that the fruit life is not always killed by that process. All fruits have some of the peculiarities of bacterial life themselves. We can look upon them, large as they are, as being endowed with some of the same natural characteristics of the Saccharomyces, in that they lose sugar and set free an equal weight of alcohol and carbonic acid gas.

Pasteur is authority for this, and he proved it absolutely by experiments, ascertaining by weight the loss of sugar and the relative production of alcohol and carbonic acid gas.

Spoilage is liable, of course, after the alcohol is produced, because this is a food for the spores of germs which have been dormant in the cans up to this time. They will

immediately seize upon this for development and spoiled goods will result. It is of course a very material advantage to the canner to preserve as much as possible of the fruit flavor and this may be done only by cooking as little as possible, but if he is troubled with Springs, it is evident that the process has been too light to kill the fruit life.

It is also a well-known fact among canners, that if their products are not canned with dispatch and processed before any fermentation takes place, there is liability of spoilage, unless the process be increased. Sometimes the goods will spoil from this cause after a very much longer process at a higher temperature. The reason is the same, fermentation started and new products were formed by that fermentation which furnished food for a much more resistant class of bacteria.

The necessity of using only sound fruits in a light process now becomes clear. If any rotten or diseased portions find their way into the cans, of course the products of that bacterial action go in also, and they are food for that class of spores whose heat-resisting powers are always menacing the canner and preserver.

Going a step in this direction, we might say something along the line of cleanliness in the work of canning and in the preparation of the food products to be preserved. Certainly, if foreign substances find their way into the goods, there will be cans here and there in the pile of finished stock that will spoil, most unaccountably to the manager, who had apparently treated all alike. A very small particle of foreign matter will cause a can to spoil sometimes, because it may contain nutrient food for spores of bacteria which would ordinarily remain dormant in the regular process of uncontaminated stock. Many interesting experiments may be made profitable along this line. Take a can of tomatoes and add a small quantity of milk, give it the regular tomato process, and then after a couple of weeks open it, and you will find it disagreeably sour, perhaps in less time than that. Then try a little corn with tomatoes after the same manner and see the result. The canner should never add any foreign substance to his goods without first ascertaining what properties it contains that might furnish food for the spores of bacteria which in his ordinary process are dormant.

There is a widely circulated belief among canners that the green parts and cores of certain fruits and vegetables will cause spoilage unless they be removed, and while it is no doubt an advisable proceeding from a standpoint of having best quality, yet those things have very little to do with spoilage. If the green parts be cooked tender, they will keep just as well as the ripe; the only difference, if any, will be a little more cooking.

Sterilization, then, is a misapplied term, and is only real when all life is absolutely killed within the can. To say that any package is perfectly sterilized means that a heat not less than 250° F., continued for at least one hour, has been given it, and there is some doubt if even this is sufficient in some cases. However, with due care goods will keep with varying temperatures, although we cannot say that they are perfectly sterilized.—THE TRADE, December 2, 1898.

A number of special articles on Bacteria, Sour Corn, etc., will be found in the copies of THE TRADE of 1898.